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SOUTHEAST UTAH GROUP RESEARCH PLAN

ARCHES NATIONAL PARK
CANYONLANDS NATIONAL PARK
NATURAL BRIDGES NATIONAL MONUMENT

SOUTHEAST UTAH GROUP
RESEARCH PLAN

January 1993
Arches National Park
Canyonlands National Park
Natural Bridges National Monument
National Park Service, Moab, Utah 1994

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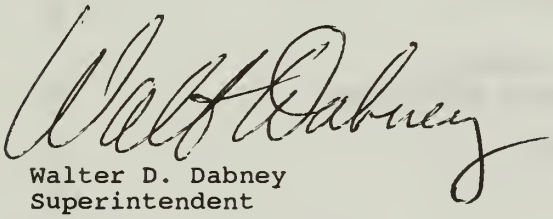

Walter D. Dabney
Superintendent
Southeast Utah Group

INTRODUCTION

The National Park Service (NPS) has made a goal in recent years to strengthen the quality of its research program. There seems to be no end to the list of needed research projects. Many parks have not accumulated adequate inventories of their resources, let alone conducted needed research on them. With so many research possibilities, it is necessary to identify and prioritize research goals. The Southeast Utah Group (SEUG) of the NPS, comprising Arches National Park (ARCH), Canyonlands National Park (CANY) and Natural Bridges National Monument (NABR), addressed this problem by inviting a panel of specialists in a variety of natural resource fields to discuss research needs of SEUG. Due to a heavy snowstorm falling the weekend the panel was held, not all of the participants were able to attend the meeting. Though not attending, they still made contributions through correspondence. On the final day of the discussion land managers from the NPS, Bureau of Land Management (BLM) and U.S. Forest Service (USFS) were presented the results of the panel's work and invited to contribute suggestions to the priority list.

This panel was directed only at the natural resources of SEUG. Cultural resources were not addressed. Because some of the natural resource disciplines were not represented at the January meeting, a second meeting was held in February 1993 to discuss the long-term monitoring program. This meeting was held at the University of Utah.

Non-biological natural resources, such as geological, paleontological and Quaternary resources are important natural resources of the parks, as are air quality, night sky and natural quiet. There are many critical information needs regarding these issues, some of which are described in the introduction. Addressing these needs, however, was beyond the scope of the panel. Consequently, such issues were not included in the information need identification and prioritization process.

THE TACTICAL STEP DOWN PROCESS

A planning tool known as a tactical step-down process (Phenicie and Lyons 1973) was used to structure the meeting. The process was initiated by the development of an overall program goal statement, or "top box," which was placed at the top of the diagram. The group then determined what steps were necessary to achieve the stated goal. These actions were placed at the next lower level of the diagram and the pattern was repeated until individual research projects or management actions were identified. At each level, the following test was applied: "If, and only if, these actions are accomplished, will the action/goals in the diagram level above be accomplished?"

THE NATIONAL PARK SERVICE MANDATE

The Organic Act that created the National Park Service mandated that this agency would "...conserve the scenery and the natural and historic objects and the wildlife therein; and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Contained in the act, then, is a mandate for NPS to allow ecosystems to exist and evolve under natural conditions and to manage human use so that it does not impair these systems' long-term, natural functioning. Since change is a part of all systems, a fundamental need is to be able to distinguish between natural and man-caused change.

The primary purpose of this panel was to identify and prioritize what information is needed for managers of SEUG to carry out the NPS mandate, in light of the specific challenges SEUG faces. There are two categories of needs: 1) ecosystem characterization (on individual, species, population and system levels) necessary for understanding basic relationships and functioning of ecosystems, and 2) shorter term research directed towards solving immediate management needs. In addition, long-term monitoring of resources is necessary to distinguish natural versus anthropogenic change, to identify needed

management actions and/or to identify additional research needs. For this reason, the panel was asked to examine the long-term monitoring program as well.

NATURAL RESOURCES OF SEUG

Regional Setting and Tourism

The SEUG manages Arches National Park, Canyonlands National Park and Natural Bridges National Monument. The parks lie within Grand, Garfield, San Juan and Wayne Counties of southeastern Utah. These counties, as well as local governments and the Utah Travel Council, all actively promote tourism in Canyonlands, Arches and Natural Bridges. Adjacent federal and state lands receive visitation as well, including Glen Canyon National Recreation Area, Dead Horse Point State Park, the Moab and Richfield Districts of the Bureau of Land Management and the Manti-La Sal National Forest. The location of the parks within this regional complex of public lands is one of the most important aspects determining visitation patterns, as well as resource management problems and programs.

Park visitation has risen dramatically over the last decade. In 1980, less than 60,000 people visited Canyonlands, but by 1985 there were almost 125,000 visitors. The number of visitors reached 342,710 in 1991, 388,122 in 1992, and rose to 434,844 visitors in 1993. Arches had 150,000 visitors in 1965, 350,000 in 1985 and 700,000 in 1991. Doubling time went from 20 years to 6 years. Visitation reached 773,678 in 1993. It took this park from its establishment in 1920 until the 1980's to serve one million visitors; in the near future, this is the expected **yearly** visitation. Natural Bridges has experienced similar increases. In 1993 the monument had 152,304 visitors, a 12% increase over 1992.

The number of visitors is unevenly distributed within the districts of Canyonlands, partly due to access and partly due to visitor interest. The number of visitors to the River District is highly controlled by a permit system. In 1993 11,075 visitors were issued river permits. The Maze District has the next lowest number of visitors, with 9,353 in 1993. Some 178,171 people visited the Needles and 236,245 visited the Island in 1993. A Backcountry Management Plan, currently in preparation, should help regulate visitor numbers and allocate visitor impacts to those zones of the park most capable of withstanding high use.

ARCHES

Climate

Arches National Park is 16 miles (26.7 kilometers) from north to south and 8 miles (13.3 kilometers) from east to west. There are a total of 73,379 acres (29,708 hectares) of land within the legislative boundaries of the park. The climate of Arches is arid. It is characterized by hot, dry summers and cool to cold winters. The average annual precipitation of the area is 7.95 inches (202 millimeters). Mean annual temperature is 56° Fahrenheit (F) (13.3° Celsius (C)) and the extreme temperatures are -8° F (-22.2° C) and 111° F (43.9° C). Precipitation peaks occur in March and August. Snow falls between November and March.

Geology

Arches National Park is largely covered by exposed bedrock, weakly developed soils and sand dunes. The park was established because of its unique geologic features, in particular the massive, spectacular natural rock arches formed in the Entrada Sandstone. The geology of Arches is largely determined by the collapsed salt anticline in Salt Valley and to a lesser extent by the collapsed Moab and Cache Valley anticlines. There are ten major sedimentary formations exposed in the park ranging in age from the Pennsylvanian Paradox formation to the Cretaceous Mancos Shale. In stratigraphic order, formations include Paradox, Honaker Trail, Cutler Group, Moenkopi, Chinle, Wingate Sandstone, Kayenta, Navajo Sandstone, Entrada, Morrison, Cedar Mountain, Dakota Sandstone and Mancos Shale. The Paradox formation of salt and gypsum evaporates is a highly plastic formation which has formed the salt anticlinal structures in the park, which collapsed when ground water

eroded the salt. The majority of the park surface is occupied by the Navajo and Entrada sandstones, with the erosion of the Entrada being responsible for the majority of the 2000 arches, natural bridges and rock openings found within the park boundaries. The cliff-forming Wingate formation exposed along the Colorado River forms the south boundary of the park. Together with the associated Kayenta, Chinle and Moenkopi formations, it forms impressive eight hundred foot cliffs.

Soils

The soils in the park are derived from the local sandstones and are classified as well-drained, fine-grained sandy loams, of predominantly eolian origin with little organic material. The soils are of yellowish-reddish color and the soil depth varies greatly. Approximately 90 percent of the soil in the park falls into the Rizno-Begay Complex. These are soils that are characterized by slopes of 2-10 percent and are fine sandy loams. The Rizno soils are found on ridges and close to rock outcrops, Begay soils are found in open areas and are deeper. These two soil types are closely intermingled and cannot be separated for mapping purposes. Rizno soils are 4-20 inches (10-50 centimeters) in depth, Begay soils are as deep as 60 inches (150 centimeters). Both soils are well drained and contain less than one percent organic matter. The vegetation associated with the Rizno soils is comprised of blackbrush Coleogyne ramosissima, Mormon tea Ephedra viridis, pinyon pine Pinus edulis and Utah juniper Juniperus osteosperma. Begay soils support a vegetation type constituted of galleta Hilaria jamesii, Indian ricegrass Stipa hymenoides, Mormon tea and needle and thread grass Stipa comata.

Vegetation

The vegetation of the park can be divided into twelve vegetative communities. These are blackbrush/ shadscale Coleogyne ramosissima/ Atriplex confertifolia, Garrett saltbush/ mat saltbush Atriplex garrettii/ Atriplex corrugata, Indian ricegrass/ galleta/ Mormon tea Stipa hymenoides/ Hilaria jamesii/ Ephedra viridis, Fremont cottonwood/ sandbar willow/ tamarisk Populus fremontii/ Salix exigua/ Tamarix ramosissima, blackbrush Coleogyne ramosissima, pinyon pine/ Utah juniper Pinus edulis/ Juniperus osteosperma, snakeweed/ shadscale/ Mormon tea Gutierrezia sarothrae/ Atriplex confertifolia/ Ephedra viridis, purple sage/ shinnery oak/ Utah juniper Poliomintha incana/ Quercus havardii/ Juniperus osteosperma, sand sage/ purple sage/ Indian ricegrass Artemisia filifolia/ Poliomintha incana/ Stipa hymenoides, greasewood/ four-wing saltbush Sarcobatus vermiculatus/ Atriplex canescens, shadscale/ Garrett saltbush Atriplex confertifolia/ Atriplex garrettii and maidenhair fern/ Jones reedgrass Adiantum capillus-veneris/ Calamagrostis scopulorum.

Mammals

Major mammals common to the park are the Western pipistrel Pipistrellus hesperus, gray fox Urocyon cinereoargenteus, bobcat Lynx rufus, white-tailed antelope ground squirrel Ammospermophilus leucurus, rock squirrel Spermophilus variegatus, Colorado chipmunk Eutamias quadrivittatus, Apache pocket mouse Perognathus flavescens, Ord kangaroo rat Dipodomys ordi, canyon mouse Peromyscus crinitus, deer mouse P. maniculatus, pinyon mouse P. truei, Northern grasshopper mouse Onychomys leucogaster, desert woodrat Neotoma lepida, porcupine Erethizon dorsatum, blacktailed jackrabbit Lepus californicus, desert cottontail Sylvilagus auduboni, mule deer Odocoilus hemionus, desert bighorn sheep Ovis canadensis nelsoni, striped skunk Mephitis mephitis, ringtail Bassariscus astatus and badger Taxidea taxus.

Birds

Common bird species likely to be found in the park are the red-tailed hawk Buteo jamaicensis, mourning dove Zenaidura macroura, common nighthawk Chordeiles minor, white-throated swift Aeronautes saxatalis, violet-

green swallow Tachycineta thalassina, ash-throated flycatcher Myiarchus cinerascens, Say's phoebe Sayornis saya, scrub jay Aphelocoma coerulescens, common raven Corvus corax, pinyon jay Gymnorhinus cyanocephalos, plain titmouse Parus inornatus, canyon wren Catherpes mexicanus, rock wren Salpinctes obsoletus, loggerhead shrike Lanius ludovicianus, gray vireo vicinior, black-throated gray warbler Dendroica nigrescens, black-throated sparrow Amphispiza bilineata and dark-eyed junco Junco hymenalis, Cooper's hawk Accipiter cooperi, golden eagle Aquila chrysaetos, red-tailed hawk Buteo jamaicensis and the northern harrier Circus cyaneus.

Herptofauna

Common herptofauna of the park are the red spotted toad Bufo punctatus, Woodhouse toad B. woodhousei, collared lizard Crotaphytus collaris, short-horned lizard Phrynosoma douglassi, sagebrush lizard Sceloporus graciousus, eastern fence lizard S. undulatus, tree lizard Urosaurus ornatus, leopard lizard Gambelia wislenzenii, side-blotched lizard Uta stansburiana, western whiptail Cnemidophorus tigris, gopher snake Pituophis catenifer, common garter snake Pituophis catenifer and the midget faded rattlesnake Crotalus viridis concolor.

Sound

Ambient noise levels in the park are assumed to be low. The degree of silence one encounters in most areas of Arches is one of its great resources. Any noise detected in the area may be associated with wildlife activity, backcountry hikers or an occasional high altitude aircraft. Noise levels should be monitored to assess baseline levels and track future changes.

Night Sky

Without the lights from a metropolitan area and the relatively clear air, the night sky resources of the park are outstanding. When located on top of a plateau, one has a nearly 360 degree view of the stars. Numerous visitors, particularly those from the eastern United States or urban areas comment on this resource.

Paleontological Resources

Stratigraphic features of the park date to the Cretaceous, Jurassic, Triassic, Permian and Pennsylvanian. In stratigraphic order, the formations include the following: Paradox, Honaker Trail, Cutler Group, Moenkopi, Chinle, Wingate Sandstone, Kayenta, Navajo Sandstone, Entrada, Morrison, Cedar Mountain, Dakota Sandstone and Mancos Shale. While paleontological resources are known from these formations, little is known of the paleontological resources within the park.

One known paleontological resource from within Arches is the highly significant dinosaur trackway in the boundary of the Entrada and Summerville formations. Tracks of carnivorous dinosaurs (terapods) dating to the Late Middle Jurassic to Late Jurassic cover an area of at least 110 square miles (300 square kilometers) on lands jointly managed by the NPS and the BLM. Only a cursory reconnaissance of these tracks has been made and detailed information on the extent of the megatrackway within the park is presently unknown. With only three "megatrackways" known to exist in North America, the Arches site is of national significance. Furthermore, the Moab megatrackway is the only Jurassic trackway and it is the oldest known example of this phenomenon. A detailed and systematic paleontological investigation of this site is urgently needed. Without such an inventory, this unique and highly significant resource cannot be preserved, protected or presented to the public.

In 1993, a dinosaur fossil, Camarasaurus, was identified from the Morrison Formation within the park. In addition, the uncomformity between the Morrison Formation (Jurassic) and the Cedar Mountain Formation (Cretaceous) is attracting considerable attention among paleontologists. These two formations exist within the park.

Quaternary Resources

The Quaternary is the geological period comprised of the Pleistocene and Recent Epochs. Like older paleontological resources, little is known of the Quaternary resources of Arches, but the few studies that have been conducted indicate that highly significant Quaternary resources exist, including at least one mammoth site.

For example, Late Wisconsin and Late Holocene pack rat middens from Bison Alcove in the park have yielded important information about changes in paleo-climate and vegetation. Additional pack rat midden studies, as well as studies of the Park's geomorphology, including paleosols, alluvium and erosion patterns, paleohydrology, tree-rings, etc., will yield highly important information about the past. This information will not only provide scientific data, but will allow better management of soils, vegetation and other natural resources. Quaternary and Pleistocene data also may prove critical in our understanding of global warming and other current climatic trends.

CANYONLANDS

Canyonlands National Park is 32 miles (52 kilometers) from north to south and 17 miles (28 kilometers) from east to west. There are a total of 337,570 acres (83,380 hectares) of land within the legislative boundaries of the park all Federally owned. The Park has been expanded since it was originally established in 1964 to its present size of 337,370 acres centered around the confluence of the Green and Colorado Rivers. The topography of the area is diverse, ranging from open flats to steep-walled cliffs. The area has been greatly affected by geologic activity associated with the salt intrusions of the Paradox formation, and the landscape has been carved by the effects of wind and water and preserved by the arid climate and lack of earthquake activity. This has produced a landscape dominated by red sandstone formations such as arches, fins, balanced rocks, mesas, canyons and spires. The rivers divide the park into three geographical districts: the Island in the Sky District (ISKY) is the triangle of land between the two rivers, the Needles District (NEED) lies east of the Colorado River and the Maze District (MAZE) lies to the west of the Green and Colorado Rivers. Horseshoe Canyon Detached Unit is managed as part of the Maze District since it also lies west of the Green River. In addition, the Green and Colorado River corridors are managed as a fourth separate district of the park, the River District (RIVER). While these are administrative districts, they do have some correspondence with the distribution of resources in the park.

Climate

Canyonlands' climate, like all of Utah's climate (Ruffner 1985), is determined by its distance from the equator, its elevation above sea level, its location relative to storm paths over the Intermountain West, and its distance from the principal moisture sources, the Pacific Ocean and the Gulf of Mexico.

Temperatures in the park vary with altitude and latitude. In Needles at an elevation of 5,040 feet for the years 1965-1986, the annual high was 107° F, the low was -16° F, the normal maximum temperature was 68.3° F, the normal minimum was 37.8° F. The monthly maximum amount of precipitation was 4.43 inches in October 1972, and the average annual precipitation was 8.62 inches. The greatest amount of precipitation in a 24 hour period was 1.12 inches in October 1986.

In the Island in the Sky at an elevation of 5930 feet for the years 1965-1986, the record high temperature was 102° F in July 1971, the record low was -8° F in December 1978. The normal maximum temperature was 64.1° F, and the minimum normal temperature was 42.2° F. The monthly maximum precipitation was 5.02 inches in October 1972, and the normal annual precipitation was 9.27 inches. The greatest precipitation in a 24 hour period was 1.76 inches in April 1978 (Brough et al. 1987). Potential

evapotranspiration exceeds precipitation, making soil moisture a crucial environmental factor.

Geology

Canyonlands is characterized by sedimentary rock which has been deformed by anticlines, synclines and monoclines. The Green and the Colorado Rivers have cut huge canyons in the Colorado Plateau, while countless side drainages amidst Colorado Plateau uplifting have literally cut a maze of canyons leading toward the rivers. Above the confluence, a long narrow mesa, known as the Island in the Sky rises. The White Rim Sandstone is exposed on the shelf below the Island. The forces of erosion have created numerous standing rocks and odd geological formations throughout the park. The uniquely banded red and white sandstone of the Cedar Mesa Formation is exposed in the Needles and Maze Districts. In stratigraphic order, formations include Paradox, Honaker Trail, Lower Cutler Beds, Organ Rock Shale, White Rim Sandstone, Moenkopi, Chinle, Wingate Sandstone, Kayenta and Navajo Sandstone.

Soils

The entire Canyonlands physiographic section is characterized by bare rock surfaces with sparse soil and vegetation (Stokes 1988). This makes soil, where it occurs, a major natural resource. The Soil Conservation Service (Lammers 1991) published a soil survey and maps containing information that can be used in land management and land-planning programs in Canyonlands. As explained by Lammers (1991), the soils in the park vary widely in their characteristics, but most soils in the park are dry and hot.

Vegetation

The vegetation of Canyonlands includes the following communities: blackbrush/ shadscale *Coleogyne ramosissima*/ *Atriplex confertifolia*, Garrett saltbush/ mat saltbush *Atriplex garrettii*/ *Atriplex corrugata*, Indian ricegrass/ galleta/ Mormon tea *Stipa hymenoides*/ *Hilaria jamesii*/ *Ephedra viridis*, Fremont cottonwood/ sandbar willow/ tamarisk *Populus fremontii*/ *Salix exigua*/ *Tamarix ramosissima*, blackbrush *Coleogyne ramosissima*, pinyon pine/ Utah juniper *Pinus edulis*/ *Juniperus osteosperma*, snakeweed/ shadscale/ Mormon tea *Gutierrezia sarothrae*/ *Atriplex confertifolia*/ *Ephedra viridis*, greasewood/ four-wing saltbush *Sarcobatus vermiculatus*/ *Atriplex canescens*, shadscale/ Garrett saltbush *Atriplex confertifolia*/ *Atriplex garrettii* woodyaster/ galleta *Xylorhiza* spp./ *Hilaria jamesii* amsonia/ hymenopappus *Amsonia tomentosa*/ *Hymenopappus filifolius*, exotic grassland *Bromus tectorum*/ *Salsola iberica* and maidenhair fern/Jones reedgrass *Adiantum capillus-veneris*/ *Calamagrostis scopulorum*. There are also small, isolated Douglas fir *Psuedotsuga menziessii* communities.

The pinyon pine-juniper community is the most extensive vegetation type, covering approximately 121,800 acres (48,720 hectares). The saltbush or snakeweed communities are next in coverage accounting for 61,500 acres (36,600 hectares). Blackbrush communities extend over 64,500 acres (25,800 hectares) in the park. Grassland communities account for 3,400 acres (13,600 hectares). The sagebrush community covers 7,600 acres (3000 hectares), while the riparian community encompasses roughly 4,000 acres (1600 hectares). The Douglas-fir relict community encompasses less than 400 acres (160 hectares); the hanging garden community is the smallest vegetal component covering less than 80 acres (30 hectares). Ponderosa pine *Pinus ponderosa* and quaking aspen *Populus tremuloides* are present but not extensive enough to be designated as a community types.

Mammals

Canyonlands is important habitat for desert bighorn sheep *Ovis canadensis nelsonii*. In addition to this large mammal, other mammal constituents of the park are the western pipistrel *Pipistrellus hesperus*, coyote *Canus latrans*, gray fox *Urocyon*

cinereoargenteus, whitetailed antelope squirrel Ammospermophilus leucurus, Colorado chipmunk Eutamias quadrivittatus, canyon mouse Peromyscus crinitus, deer mouse P. maniculatus, pinyon mouse P. truei, desert woodrat Neotoma lepida, porcupine Erethizon dorsatum, blacktailed jackrabbit Lepus californicus, desert cottontail Sylvilagus auduboni and mule deer Odocoilus hemionus.

Birds

Common bird species likely to be found in the park are the turkey vulture Cathartes aura, northern harrier Circus cyaneus, red-tailed hawk Buteo jamaicensis, American kestrel Falco sparverius, mourning dove Zenaidura macroura, great horned owl Bubo virginianus, common nighthawk Chordeiles minor, white-throated swift Aeronautes saxatalis, northern flicker Colaptes auratus, hairy woodpecker Picoides villosus, ash-throated flycatcher Myiarchus cinerascens, horned lark Eremophila alpestris, violet-green swallow Tachycineta thalassina, cliff swallow Hirunda pyrrhonta, scrub jay Aphelocoma coerulescens, pinyon jay Gymnorhinus cyanocephalos, common raven Corvus corax, plain titmouse Parus inornatus, canyon wren Catherpes mexicanus, western bluebird Sialia mexicana, American robin Turdus migratorius, loggerhead shrike Lanius ludovicianus, Bell's vireo Vireo bellii, solitary vireo V. solitarius, gray vireo V. vicinior, black-throated gray warbler Dendroica nigrescens, green-tailed towhee Pipilo chlorurus, rufous-sided towhee P. erythrophthalmus, black-throated sparrow Amphispiza bilineata, dark-eyed junco Junco oreganus, white-crowned sparrow Zonotrichia leucophrys and Brewer's blackbird Euphagus cyanocephalis.

Herptofauna

Herptofauna found in the Park include the red spotted toad Bufo punctatus, Woodhouse toad B. woodhousei, Great Basin spadefoot toad Scaphiopus intermontanus, tiger salamander Ambystoma tigrinum, plateau striped whiptail Cnemidophoras velox, collared lizard Crotaphytus collaris, short-horned lizard Phrynosoma douglassi, sagebrush lizard Sceloporus graciousus, eastern fence lizard S. undulatus, tree lizard Urosaurus ornatus, desert night lizard Xantusia vigilis, side-blotched lizard Uta stansburiana, western whiptail Cnemidophorus tigris, gopher snake Pituophis melanoleucus deserticola, western terrestrial garter snake Thamnophis elegans vagrans and the midget faded rattlesnake Crotalus viridis concolor.

Sound

Ambient noise levels in the park are low. The degree of silence one encounters in most areas of the Park are one of its great resources. Any noise detected in the area may be associated with wildlife activity, backcountry hikers or an occasional high altitude aircraft. With increased oil and gas activity in the area and the potential for mining in the future, mineral development could add significantly to noise levels. Monitoring and documenting background noise levels before mineral activity increases is essential.

Clean Air and Night Sky

Many visitors come to Canyonlands for its magnificent vistas and clear night sky. Without the lights from a metropolitan area and with the relatively clear air, the air of the park is one of its greatest resources. Air quality is also a resource threatened by increasing local and regional development. Moab, the closest town, has poor winter air quality due to the use of wood-burning fuel. Coal-burning power plants such as those in Huntington, Utah and Page, Arizona, also impair the air quality of the park. These sources of pollution are not regulated by NPS, despite their adverse impact on the parks.

Water and Riparian Resources

The Colorado and Green Rivers form the heart of Canyonlands National Park. There is one permanent stream, Salt Creek, in the Needles District, which is a significant riparian

resource. It forms critical habitat for fish, amphibians, aquatic insects, small mammals, other animals and plants.

Tamarisk growth has largely altered natural vegetation along the rivers and at various streams, springs and washes in the Park. The many springs, seeps and potholes in the park comprise the surface water resources of Canyonlands.

Paleontological Resources

Little is known of park paleontological resources. Formations exposed range from Jurassic Navajo Sandstone of the Glen Canyon Group, to the basal, Pennsylvanian Paradox Formation of the Hermosa Group. Based on Stokes (1988), we could expect to find fossils in Table 1.

Quaternary Resources

Ten years ago, almost nothing was known of the Quaternary resources of the park. However, with the 1985 publication of the first packrat midden analyses from the area (Betancourt and Biggar 1985), new investigations of the Quaternary resources of the park have been undertaken. Significant information has been recovered during a recent contract between the Rocky Mountain Region of NPS and the Quaternary Studies Department of Northern Arizona University (NAU). Unpublished results indicate highly significant Quaternary resources are present in the park, resources such as fossil packrat middens, bones of now-extinct megafauna, alluvium, etc. Another contract has been issued between the Rocky Mountain Region and NAU to inventory and assess Quaternary resources reported in the preliminary contract. The new contract will significantly expand the Park's ability to manage Quaternary resources.

Table 1. Fossils expected to be found in Canyonlands.

Period	Formation/Group	Expected Fossils
Jurassic	Navajo Sandstone	animal tracks
Triassic	Kayenta, Wingate, Chinle, Moenkopi	tracks of reptiles and amphibians, including dinosaurs; fossil fish; fossil plants including petrified trees
Permian	Cutler Group: White Rim Sandstone, Organ Rock Shale, Cedar Mesa Sandstone, Elephant Canyon Formation, Halgaito Shale	amphibian and reptile tracks; fusulinids, brachiopods, pelecypods, gastropods, bryozoans, echinoderms, cephalopods, corals, scaphopods, plants, vertebrates
Pennsylvanian	Hermosa Group: Honaker Trail Formation, Paradox Formation	fusulinids, brachiopods, bryozoans, corals, pelecypods, crinoids, gastropods

Climate

Natural Bridges contains a total of 7,445 acres (3010 hectares) within its boundaries. An additional 191 acres (77 hectares) is included in the right of way for the entrance road. The climate of the area is arid and is characterized by hot, dry summers and cold winters. The average annual total precipitation is 13.15 inches (33.4 centimeters). The majority of the precipitation falls between the months of July and December, 30% as summer thunderstorms. Snow falls between October and May with an average annual total snowfall of 51 inches (129.5 centimeters). Major snowfall occurs in the months of November through March. The mean annual temperature is 50.4° F (10.2° C) and the extremes range from -14° F (-25.6° C) to 103° F (39.4° C).

Geology

Elevations of Natural Bridges National Monument (NM) range between 6,000 feet (1830 meters) and 6,600 feet (2010 meters). The land surface of the Monument is a deeply incised plateau with two major canyons, White and Armstrong, which intersect in the western part of the Monument. White Canyon is a major topographic feature of western San Juan County. The geologic features of the Monument are the result of stream erosion of the massive Cedar Mesa sandstone, a member of the Cutler formation which dates to the Permian Era. The formation is estimated to be 280 million years old. The canyons of the Monument are similar to the canyons of the surrounding area, being deeply incised into a relatively flat plateau. This is the result of uplifting of the area by the Monument upwarp and the subsequent rapid downcutting. The bridges were formed by streambed erosion (running water) and are geologically distinct from arches, which are formed by the action of groundwater, frost and wind erosion. The Cedar Mesa sandstone is between 500-1,000 feet (150-300 meters) thick and considered to be the lithified remains of a coastal barrier island-system.

Soils

Soils at Natural Bridges are poorly developed and are derived from residuum of the Moenkopi formation, a sandstone, mudstone and siltstone deposit of the Triassic era. Due to the remoteness of the monument from developed or agricultural areas, no soil survey has ever been performed.

Vegetation

Vegetation of Natural Bridges is divided into five categories: the pinyon pine-juniper community, the riparian community; rimrock communities; hanging garden communities; and Douglas fir relict communities. The pinyon pine-juniper community is the most extensive vegetation type, covering approximately 4,200 acres (1700 hectares). The rimrock community is next in coverage, accounting for 2,700 acres (1100 hectares). The riparian community accounts for roughly 400 acres (160 hectares). The Douglas fir relict community encompasses less than 400 acres (160 hectares); the hanging garden community is the smallest vegetal component covering less than 80 acres (30 hectares). Ponderosa pine Pinus ponderosa is present but not extensive enough to be designated as a community type.

The pinyon pine-juniper vegetation type is dominated by pinyon pine P. edulis and Utah juniper Juniperus osteosperma. Other major shrub components are broom snakeweed Gutierrezia sarothrae, roundleaf buffaloberry Shepherdia rotundifolia, big sagebrush Artemisia tridentata and prickly pear cactus Opuntia spp. Common forbs associated with this vegetation type are twinpod Physaria acutifolia, lobeleaf groundsel Senecio multilobatus and Holboel rock cress Arabis holboellii.

The riparian vegetation communities are dominated by Fremont cottonwood Populus fremontii with the shrub understory being comprised of sandbar willow Salix exigua, yellow willow S.

lutea and box elder Acer negundo. Of the many forbs and grasses that make up this vegetation community the principal species are phragmites Phragmites communis, horsetail Equisitum arvense and E. laevigatum and hairy goldenaster Heterotheca villosa.

The hanging garden vegetation type is characterized by moisture-loving vegetation, and often contain plants not found elsewhere in the desert. These include plants such as the maidenhair fern Adiantum capillus-veneris, cliff-brake Pellaea spp., scarlet monkey flower Mimulus eastwoodiae, death camus Zigadenus spp., columbine Aquilegia spp. and alcove bog-orchid Habenaria zothecina.

The Douglas fir community is a relict community and is characterized by Douglas fir Pseudotsuga menziesii, Utah serviceberry Amelanchier utahensis, mountain lover Pachystima myrsinites, dwarf mountain mahogany Cercocarpus intricatus and manzanita Arctostaphylos patula.

The rimrock community is a shrub-dominated type found on the canyon rims and is of mixed composition. The primary components are pinyon pine P. edulis, Utah juniper J. osteosperma, manzanita A. patula, gambel oak Quercus gambelii, broom snakeweed G. sarothrae, Utah serviceberry A. utahensis, longflower snowberry Symphoricarpos longifolius and goldenweed Haplopappus spp.

Mammals

The major mammals in Natural Bridges are the western pipistrel Pipistrellus hesperus, coyote Canus latrans, gray fox Urocyon cinereoargenteus, white-tailed antelope squirrel Ammospermophilus leucurus, Colorado chipmunk Eutamias quadrivittatus, canyon mouse Peromyscus crinitus, deer mouse P. maniculatus, pinyon mouse P. trueii, desert woodrat Neotoma lepida, porcupine Erethizon dorsatum, blacktailed jackrabbit Lepus californicus, desert cottontail Sylvilagus auduboni and mule deer Odocoilus hemionus.

Birds

Common bird species likely to be found in the Monument are the turkey vulture Cathartes aura, northern harrier Circus cyaneus, red-tailed hawk Buteo jamaicensis, American kestrel Falco sparverius, mourning dove Zenaidura macroura, great horned owl Bubo virginianus, common nighthawk Chordeiles minor, white-throated swift Aeronautes saxatalis, northern flicker Colaptes auratus, hairy woodpecker Picoides villosus, ash-throated flycatcher Myiarchus cinerascens, horned lark Eremophila alpestris, violet-green swallow Tachycineta thalassina, cliff swallow Hirunda pyrrhonta, scrub jay Aphelocoma coerulescens, pinyon jay Gymnorhinus cyanocephalos, common raven Corvus corax, plain titmouse Parus inornatus, canyon wren Catherpes mexicanus, Western bluebird Sialia mexicana, American robin Turdus migratorius, loggerhead shrike Lanius ludovicianus, Bell's vireo Vireo bellii, solitary vireo V. solitarius, gray vireo V. vicinior , black-throated gray warbler Dendroica nigrescens, green-tailed towhee Pipilo chlorurus, rufous-sided towhee P. erythrophthalmus, black-throated sparrow Amphispiza bilineata, dark-eyed junco Junco oreganus, white-crowned sparrow Zonotrichia leucophrys and Brewer's blackbird Euphagus cyanocephalis.

Herptofauna

Common herptofauna of the Monument are the red-spotted toad Bufo punctatus, Woodhouse toad B. woodhousei, Great Basin spadefoot toad Scaphiopus intermontanus, tiger salamander Ambystoma tigrinum, plateau striped whiptail Cnemidophorus velox, collared lizard Crotaphytus collaris, short-horned lizard Phrynosoma douglassi, sagebrush lizard Sceloporus graciousus, eastern fence lizard S. undulatus, tree lizard Urosaurus ornatus, desert night lizard Xantusia vigilis, side-blotched lizard Uta stansburiana, western whiptail Cnemidophorus tigris, gopher snake Pituophis melanoleucus deserticola, western terrestrial garter snake Thamnophis elegans vagrans and the midget faded rattlesnake Crotalus viridis concolor.

Paleontological Resources

Stratigraphic features of Natural Bridges date to the Permian and Triassic. The only exposed formations are Cedar Mesa and the Moenkopi. While paleontological resources are known from these formations, little is known of the paleontological resources within the Monument.

A detailed, systematic, intensive paleontological investigation of this Monument is needed. Without such an inventory, this unique and highly significant resource cannot be preserved, protected or presented to the public.

Quaternary Resources

Knowledge of Quaternary resources is limited in Natural Bridges but significant information has been recovered. The bones of Harrington's mountain goat Oreamnus harringtoni dating to 39,800 years B. P. (before present) were discovered in the Monument in a dry alcove. This is the oldest known find of this species and the only location of this animal outside of the Grand Canyon. Packrat middens dating to the same period have been found at the same alcove site and pollen recorded from those middens gives a good description of the local flora at that time. The potential for the recovery of additional significant Quaternary Resources is high and should be funded.

NATURAL RESOURCE MANAGEMENT OBJECTIVES

Natural resource management objectives for SEUG parks are to protect and preserve the outstanding features such as arches, fins and other erosional remnants; the desert plant and animal communities; air and water resources; natural quiet; and Quaternary and paleontological resources. These resources are to be managed in such a way that human impacts on these resources are minimized and that management is consistent with legislative and executive requirements and NPS policies and guidelines.

Specific management objectives (as outlined in the Resource Management Plans of the three park units) include:

•Provide for the public use and enjoyment of the backcountry areas while minimizing the environmental impacts of visitor use. This includes maintaining the primitive character of the backcountry as well as protecting the natural resources and ecological processes.

•Manage developed areas for intensive visitor use while providing for the maximum protection of the natural environment.

•Protect and perpetuate natural ecosystems and their components. Particular attention is given to unique plant species and communities, including rare, threatened, endangered and endemic species as well as pristine, disjunct and uncommon plant communities.

•Research and understand basic ecosystem processes so that human induced impacts can be distinguished from natural processes. Provide the interpretive staff with information concerning ecological processes occurring within the parks.

•Restore wherever possible the natural condition of park lands and plant communities altered by human activities.

•Mitigate, when feasible, the impacts of exotic plants wherever natural communities are threatened or where control methods are likely to be successful.

•Protect the park resources by the provision of adequate fencing to prevent impacts due to trespass by livestock.

•Maintain the high quality of the air resources in the park such that the scenic quality of the viewshed is not hampered and that deposition of particulate matter from combustion does not adversely impact park resources.

•Protect surface aquatic resources in the park such as streams, seeps, springs and potholes. Provide for the protection of the underground aquifer from pollution or drawdown such that the natural surface waters are not altered.

•Protect the unique and high quality night sky and natural quiet resources of the park.

•Prevent adverse effects to park lands and resources from outside threats due to land use and changes in ownership.

•Collect and maintain information on the geologic and erosional features of the park, thereby providing for documentation on the condition of those resources and natural changes that occur over time.

•Inventory and monitor major natural resources (vegetation, wildlife, soils, clean air, clear vistas, natural quiet and clean water) to enhance the information database and to determine changes in critical resources so that management practices can be modified promptly to reverse and mitigate adverse impacts to those resources.

•Identify and study Quaternary and paleontological resources of the park. Research should be funded to locate, identify, analyze and report on Quaternary geomorphology (including paleosols, alluvial, etc.), packrat middens, mollusks, pollen, tree-ring and other records.

•Educate the public and the staff about what has been and what can be

learned from both Quaternary and paleontological resources of the park.

•Teach the staff how to identify significant Quaternary and paleontological resources so that the resources can be reported, evaluated and monitored by scientists trained in Quaternary and paleontological research techniques.

CHALLENGES AND THREATS TO SEUG RESOURCES

The challenges that managers of SEUG face are many. Examples of the major issues facing the parks are discussed below.

VISITATION

One of the greatest problems for SEUG parks is minimizing visitor impacts on park natural and cultural resources. The presence of visitors affects the ecosystems in many ways. Noise and movement affect wildlife of all sizes, and bathing in temporary water sources leaves oils, sunscreen and repellant behind. Most dramatic is the effect visitor trampling is having on ecosystems at and below the soil surface. Recent research has demonstrated severe negative effects on populations of all soil organisms examined (Belnap et al. 1994, Belnap, unpublished data). Reductions of these populations, in turn, greatly affects nutrient cycles in these systems. Surface integrity of soils is greatly decreased in trampled areas, leading to increased water and wind erosion. Compaction of soils results in less water infiltration, greater run-off and less locally available water for plants.

ECOSYSTEMS AND/OR POPULATIONS AT RISK

Ecosystems at risk: Most ecosystems in SEUG are at risk when disturbed. The two ecosystems most impacted in SEUG are 1)riparian areas, which are being invaded by tamarisk Tamarix ramosissima, Russian olive Eleagnus angustifolia, Russian thistle Salsola iberica, and Russian knapweed Centaurea repens and 2) native grasslands that have been invaded by cheat grass Bromus tectorum, Russian thistle, halogeton Halogeton glomeratus and crested wheatgrass Agropyron cristatum. Both of these systems have been, or currently are, disturbed. Man-caused fires continually disturb riparian areas and livestock grazing has disturbed most areas of the parks.

Populations at risk: Exotic fish (plains killifish Fundulus zebrinus, green sunfish Lepomis cyanellus, carp Cyprinus carpio, channel catfish Ictalurus punctatus, fathead minnow Pimephales promelas, red shiner Notropis lutrensis and sand shiner N. stramineus) threaten the integrity of our native fish in streams and rivers. Little is known about or aquatic invertebrate populations.

Fourteen native species used to dwell in the Colorado and Green Rivers; the four remaining species are endangered (Bonytail chub Gila elegans, humpback chub Gila cypha, Colorado squawfish Ptychocheilus lucius and razorback sucker Xyrauchen texanus). In the past, all research done on these populations has been done by the U.S. Fish and Wildlife Service (USFWS) or the state of Utah. These fish are at extreme risk from upstream dam controls, toxic spills, tamarisk invasion, sedimentation and channelization.

Desert bighorn sheep populations are at risk from disease. Effects of visitation (noted above) are unknown. Island in the Sky, in conjunction with the Potash herd on BLM land, has the only healthy relict herd left in Utah. Needles had a population crash several years ago from disease, and the herd has dropped to one third its former size. The Maze and Arches both have transplanted herds that are doing well.

Peregrine falcons are recovering well. All known territories are filled. It is not known if all potential territories are filled. Mexican spotted owls have recently been found in Canyonlands; we have little information on them. Bald eagles utilize the Cataract Canyon area in the winter, but little is known about them either.

There are no federally listed threatened and endangered (T&E) vascular plant species in the parks. There are 17 state listed plants. Population studies have been started on the three most threatened of these, but these are short-term (three year), and will end soon. No monitoring protocols yet exist.

NON-RECOVERY OF DISTURBED TERRESTRIAL ECOSYSTEMS; RESTORATION

Many previously grazed grasslands are still dominated by exotic plants, although no grazing has occurred for 25 years. Other ecosystems also show little sign of recovery from disturbance. Restoration of these previously or currently disturbed areas is highly problematic. Both seeding and transplant efforts have met with limited success. No attention has been paid to restoration of microbial communities, macro-fauna or system processes such as nutrient cycling. SEUG has examples of grass, shrub and tree-dominated systems that were never utilized by livestock. Characterization of these undisturbed ecosystems can provide better understanding of what makes native communities sustainable and non-invasible. This, in turn, will provide both restoration and management goals for SEUG.

GAS AND OIL DEVELOPMENT

Gas and oil development threaten biotic resources of the park in three ways. First is the possibility of aquifer contamination when holes are drilled. Secondly, spills and leaching of buried waste is possible. Thirdly, newly constructed or improved roads lead to increased visitation to areas that are now fairly remote.

TRESPASS LIVESTOCK GRAZING

This is a major problem in Arches, where lack of fencing allows grazing of about 10% of the park. There is also a problem on the east boundary of Canyonlands. Natural Bridges has some trespass in the riparian area. Livestock trample soils and eat vegetation. See above section "Visitation" for effects of trampling.

A RESEARCH PERSPECTIVE: PAST AND CURRENT INVESTIGATIONS IN SEUG

ORGANIZATION

The Resource Management Division for all parks of SEUG is located in Moab. This division consists of a Chief, two Natural Resource Specialists and a Biologist. A National Biological Survey (NBS) Research Ecologist works in conjunction with the division. When funding is available, two seasonal Biological Technicians are hired from April-September for the long-term monitoring program (described in more detail below). Other seasonal Biological Technicians are hired on a temporary or term basis when funding is available for projects, such as desert bighorn sheep monitoring, exotic plant control, revegetation projects and others. The division has no base-funded research or project funds. Project funds come from either Washington or regional initiatives, the NBS or Natural Resources Protection Program (NRPP) funds. For monies, we compete with all parks in the nation. SEUG has traditionally done very well in competitive funding initiatives, and generally has two to four on-going projects.

PAST AND CURRENT NPS-FUNDED RESEARCH PROJECTS

The following projects in SEUG have been funded by NPS money:

1. Effects on aquatic insects, small mammals and vegetation in riparian zones by vehicles in Salt Creek, Needles district; and of hikers in Natural Bridges and Arches;

2. Rare plant survey of the three parks;

3. Population studies of three species of sensitive plants, one in each park unit;

4. Biogeography of invertebrates and plants of hanging gardens in parks throughout the Colorado Plateau;

5. Cause of disease and die-off of Utah Juniper in Natural Bridges;

6. Mexican spotted owl survey (awaiting funding);

7. Colorado River endangered fish;

8. Desert bighorn sheep census techniques, genetics and disease studies;

9. A three-year Peregrine falcon study has just been completed; and

10. Develop sampling protocols for benthic macroinvertebrates.

OTHER RESEARCH

Traditionally, any other research in the parks has occurred as a result of an individual researcher's interest and funding. Appendix II is a list of the research that has occurred in the past five years.

LONG-TERM MONITORING PROGRAM

SEUG has had a long-term monitoring program for seven years. The objective of this program is to provide information on natural variation in relatively undisturbed sites. This information can then be used to distinguish man-caused from natural change in areas receiving visitation, bringing to light needed research or management actions. Currently, the program has four components: small mammals, birds, vegetation and water. In the past, we attempted to sample herptofauna, but with little success. Sampling is done yearly in Arches, Natural Bridges and all three districts in Canyonlands.

Vegetation

Forty vegetation transects have been established in SEUG. These are located in each major vegetation type in each of the parks and districts. Cover and frequency for ground cover components (including soil litter, rock, bare ground, cyanobacteria, mosses and lichens) and all vascular plant species are estimated using a one-quarter meter nested quadrat frame. Five transects, with 20 quadrats/transect, are done at each site. Total frequency, percent frequency, percent cover and species

richness are calculated for all species, including shrubs, forbs and grasses. In the future, sites will be paired to monitor the effects of visitor impacts. A site in an undisturbed community will be paired with a site of the same community type in a human-impacted area. Some of the existing sites have been paired. Additional human-impacted sites will need to be added to the program.

Small mammals

Up to ten small mammal webs have been run each year. Two hundred traps are set out in a web for four consecutive nights. Densities and biomass are estimated using TRANSECT software. The data has been highly variable. This portion of the program may be scaled back or eliminated in the future. In 1993, trapping grids were established in the vicinity of the webs to determine whether comparisons could be made with a scaled-back effort.

Birds

For the past six years, bird transects were run in the same areas as the mammal webs. Transects were run for three mornings. The data obtained have been highly variable due to the wide range of birding skills of the observers. To improve consistency, a modified Emlen transect, based on sightings of birds within 200 meters of the transect line has been used. Observers stopped every 50 meters and recorded birds seen in five minutes. There was still a great deal of variability between observers. For this reason, the monitoring was contracted to a professional in 1993. Since bird use of riparian areas is high, two riparian zones in each of the three parks were sampled, one where visitation is high and one where visitation is limited.

Soils

Soil communities are not currently monitored in any way. If, indeed, trampling is adversely impacting these communities, this should be included as part of the program.

Water

Since 1983, 35-45 springs, streams, or plunge pools have been sampled one to two times per year. In 1992, our water quality monitoring plan was rewritten under the supervision of the Washington, D.C. office of Water Resources. In 1993, the number of sample sites was reduced to ten sites, which will be sampled three times per year. Bioassays may be included in the future if a sampling protocol can be developed.

PRIORITIZATION OF SEUG RESEARCH NEEDS

Using the tactical step-down process, the ways to identify and prioritize the information needed to manage, maintain and restore the resources of SEUG were identified (Figure 1). Next, necessary information was identified (Figure 2). The third step was to prioritize these information needs (Figure 3).

I. Identifying Information Needs: The first task under "Identification of Information Needs" was to determine the scale at which ecosystems in SEUG would be defined. The scale selected was the series level described by Brown, Lowe and Pase (1979), e.g. blackbrush, pinyon-juniper. The task of assigning series level names to the vegetative communities of SEUG has been accomplished. The second step is to delineate, map and measure the condition of the different ecosystems found in SEUG. A critical element in measuring ecosystem condition is acquiring baseline information on the natural functioning of the ecosystems. Since SEUG is fortunate enough to have relatively unimpacted examples of all the major ecosystems found in this region, characterization of these more pristine areas will provide this baseline information. This characterization will then be used to compare with more impacted areas and to provide goals for managing and restoring these other areas.

Specific types and specific effects of impacts to these ecosystems will be identified. Characteristics of the more pristine areas will be compared to conditions in more impacted areas. In addition, interactions between these different ecosystems must be understood. Methods to maintain and restore these systems to pristine conditions will then be developed.

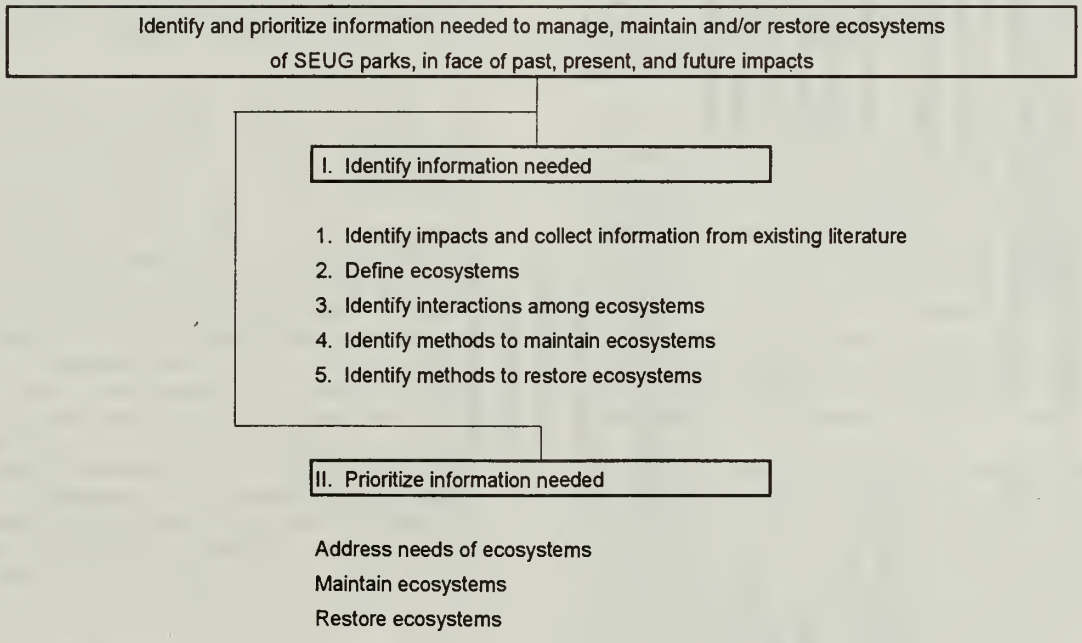
Identify and prioritize information needed to manage, maintain and/or restore ecosystems of SEUG parks, in face of past, present, and future impacts
I. Identify information needed
1. Identify impacts and collect information from existing literature
2. Define ecosystems
3. Identify interactions among ecosystems
4. Identify methods to maintain ecosystems
5. Identify methods to restore ecosystems
II. Prioritize information needed
Address needs of ecosystems
Maintain ecosystems
Restore ecosystems

Figure 1. Major tasks needed to identify and prioritize natural resource information for SEUG parks.

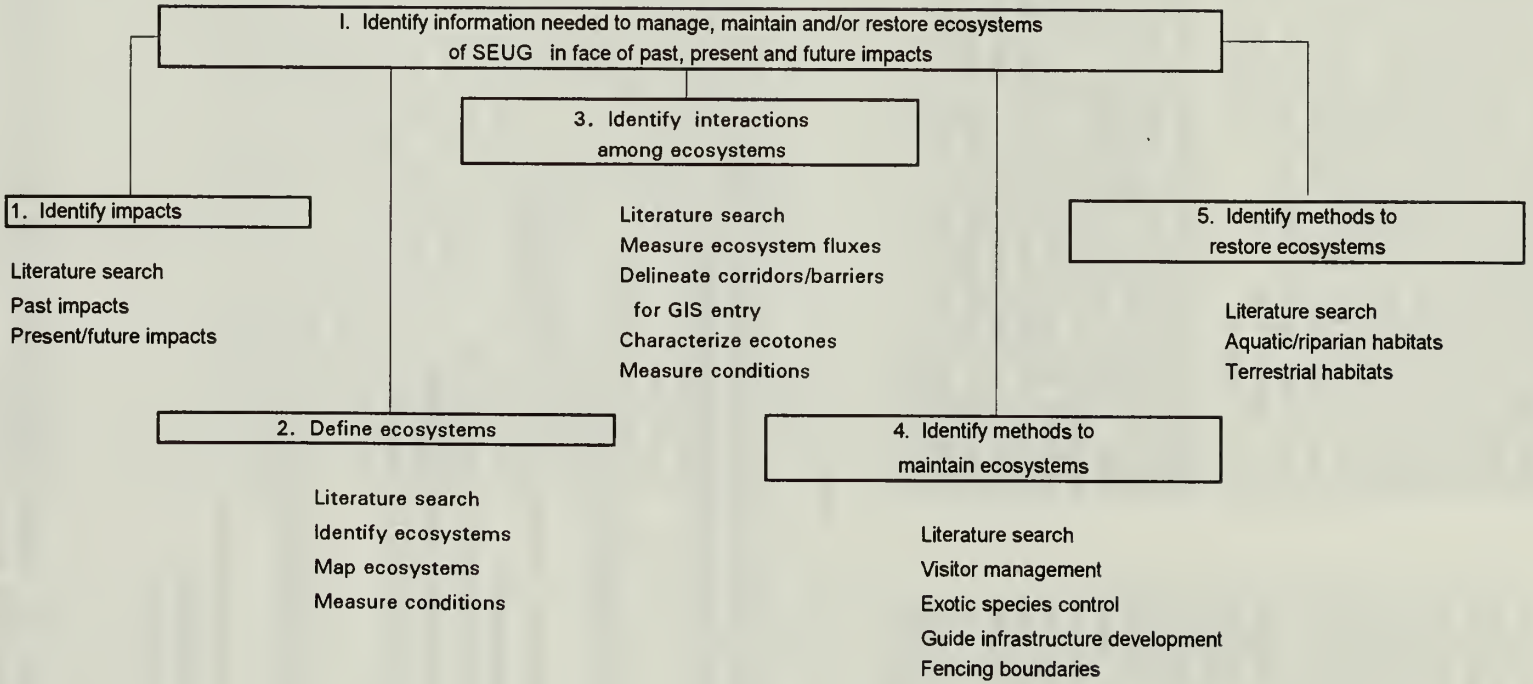

Figure 2. Identification of information needs for SEUG parks.

II. Prioritizing Information Needs: Following identification of information needs, these needs were prioritized. Given the large number of research or information needs, only the most important ones were listed in Figure 3. Table 2 lists in outline form, and in more detail, the top research needs. The seven most pressing needs were ranked. The rest were listed under the categories of "Critical," "More Important" or "Important." It must be stressed that all needs listed in this section were deemed of great importance to the parks, and should be addressed as soon as possible. Budgetary constraints were the only reason this list was divided into critical, more important, and important needs. All information needs are addressed in Resource Management Plans for each of parks (Hauke and Coulam 1993).

Outline of SEUG research needs: The top priority research needs are detailed in Research Funding Proposals (RFP) in Appendix III. Selected unranked research needs are detailed in funding proposals in Appendix IV. Neither of these appendices are complete. More RFP's will be needed to address all issues in detail.

The top priorities are systems or populations at risk of being lost or irreversibly damaged unless immediate action is taken. Of the seven top priorities, river flow and visitor impact issues are so critical, and have such widespread implications, that the panel was unwilling to say that either is more important. Characterization of ecosystem processes was also ranked as a number one critical need, because so many other research projects will hinge on this information. For that reason, there are three number one priorities for SEUG to address, followed by the next four most important topics. Appendix III contains more detail on each of the ranked priorities.

II.1. Characterization of basic system processes in more pristine examples of different ecosystems

Basic ecosystem components and processes need to be identified and characterized to provide baseline information for 1) evaluating ecosystem health of more impacted areas; 2) triggering management actions when needed; and 3) to provide restoration and management goals.

II.1. River flow, sediment transport and riparian vegetation

The characteristics of the riverine habitat have changed dramatically in the past century. Invasion of tamarisk Tamarix ramosissima has stabilized riverbanks, holding sandbars in place that were otherwise annually reshaped by spring runoff. Associated backwaters, important nursery habitat for native fishes, have been reduced in availability and quality. Encroachment by tamarisk has narrowed the channel (Graf 1976), causing the river to become deeper and swifter in habitats used by native fishes. Flow rates and sedimentation processes have been altered by dam development upstream, creating a modified environment for native species that continues to threaten their existence.

II.1. Visitor impacts to ecosystems: soil surface disturbance and water quality

The third number one priority was research on the effects of visitors on soils and soil biota of the parks. SEUG has been heavily impacted by recreational visitation. Research shows that trampling of the sensitive soils can have a dramatic impact on stability and nutrient cycles of ecosystems (Belnap et al. 1994). Further research is needed to determine the extent of these impacts and how best to manage visitor use.

Visitors can also affect water quality in the parks. Air temperatures are often high, and people refresh themselves in springs and streams. The effects of lotions, sunscreens, insect repellents and sediment on the flora and fauna of these water sources are unknown.

II.4. GIS

Panel members agreed that it was critical to develop a working Geo-

graphic Information System (GIS) for further management planning. Canyonlands and Arches do not have accurate and up to date vegetation maps. This information is vital to establishing a GIS and assessing long term change in the ecosystem. Funding for vegetation mapping has proven difficult to obtain but is desperately needed. Other necessary layers include soils, geology, topography, hydrology, sensitive plant and animal distributions, rare species, land use and ownership, visitor use patterns and infrastructure development.

II.5. Endangered species: fish

Research on the status of the four endangered species of fish in the Upper Colorado River basin has been conducted by U.S. Fish and Wildlife Service (USFWS), Utah Division of Wildlife Resources (UDWR), Bureau of Reclamation (BOR), and NPS. The Green River and Colorado River in Canyonlands support significant populations or concentrations of these species in habitat important to their survival and recovery (Valdez 1990, Valdez and Williams 1993). The lower 76 kilometers of the Green River in Canyonlands supports one of the highest densities of young Colorado squawfish Ptychocheilus lucius in the basin. One of only six populations of humpback chub Gila cypha in existence occurs in the Colorado River in Cataract Canyon. Also, the most recent records of bonytail chub Gila elegans from the upper basin are from Cataract Canyon (Valdez and Moretti 1994). Razorback suckers Xyrauchen texanus are rare in Canyonlands.

Funding from NRPP for endangered fish work is best directed at monitoring population trends, and developing management activities to benefit these and sympatric native species. Specific research topics to be considered are: (1) continue to monitor fish composition and abundance in Canyonlands, (2) identify and quantify loss of Colorado squawfish from the Green and Colorado Rivers to Lake Powell, (3) monitor humpback chub in Cataract Canyon (UDWR discontinued this program after October 1992), (4) survey Canyonlands for razorback suckers, (5) remove tamarisk from riverbanks to reestablish access by fish to floodplain nursery habitats, (6) investigate juvenile Colorado squawfish abundance and habitat use in lower Green River and Cataract Canyon, and (7) survey Canyonlands for bonytail chub. Investigations of Colorado River native fishes will consider causative factors leading endangerment and management activities minimize or eliminate these factors. Investigations on sedimentation and channelization will be integrated with native fish investigations to assess habitat changes from geomorphic processes.

II.6. Sensitive species

The following sensitive species were considered most at risk and in need of immediate attention: Mexican spotted owl, desert bighorn sheep, southwestern willow flycatcher, Kachina daisy and Canyonlands lomatium. For these species, questions that need to be addressed include minimum viable population levels; habitat needed to support these populations; effects of current land management practices on these populations, visitor impacts on these species; and maintenance of migration corridors within and across park boundaries.

II.7. Exotic plant control

Exotic species are of constant concern. Methods of controlling these species, including timing of treatment and the use of chemical controls, needs systematic investigation.

II. Prioritize information needed to manage, maintain and/or restore ecosystems of SEUG parks, in face of past, present, and future impacts using identified information in part 1.

Address ecosystem needs using pristine area characterization as management goals

Critical needs

1. Characterize ecosystem processes in relatively undisturbed areas
1. River flows and riparian
1. Visitor impacts
4. GIS
5. Endangered fish populations
6. Sensitive species
7. Exotic plant control

More important needs (unranked)

Identify and define ecosystems
Map ecosystems
Identify impacts
Measure ecosystem conditions
Water pollutant monitoring
Neotropical migrants
Above-ground invertebrates
Flow rates from springs and seeps
Amphibians
Detritus: aquatic and terrestrial

Important needs (unranked)

Identify interactions between ecosystems
Corridors/Barriers/Ecotones (GIS)
Water quality monitoring
Climatic factors
Distribution/ population dynamics of other sensitive species
Water flux
Pothole water warming
Trophic dynamics, predator studies
Ecosystem productivity
Chemical fluxes

Maintain ecosystems using pristine area characterization as management goals

Critical needs (unranked)

Relict area characterization
Visitor management
Exotic species control
Fencing of boundaries
Guide infrastructure development

Restore ecosystems using pristine area characterization as management goals

Critical needs (unranked)

Relict area characterization
Literature search
Aquatic and riparian habitats
Terrestrial habitats
Severely degraded systems

More important needs (unranked)

Aquatic and riparian habitats
Moderately degraded

Important needs (unranked)

Aquatic and riparian habitats
Terrestrial habitats
Degraded, but stable

Figure 3. Prioritization of identified research needs for SEUG parks.

Table 2. Detailed outline of prioritized SEUG research needs.

Research needs were placed in one of three categories: "Critical," "More Important" and "Important." The top seven priorities of the "Critical" research needs are ranked. The remaining critical needs are unranked, as are all needs in the "More Important" and "Important" categories. Additional details on priority needs are presented in Appendix III. Numbers in parentheses correspond to the RMP statements in Appendix I, as explained in the text. Applicable RMP project statements are listed after the research need statements. All of these needs are addressed in further detail in the RMP project statements (Hauke and Coulam 1993). Codes in parentheses refer to approved RMP Natural Resource statements for Arches (A), Canyonlands (C) and Natural Bridges (N) (e.g. A-23 corresponds to statement Arches-N-023). A list of RMP statements is provided in Appendix I. Note that subheadings with no RMP cross-reference are addressed in RMP statements listed after the parent heading.

CRITICAL RESEARCH NEEDS: TOP PRIORITIES

II.1 CHARACTERIZATION OF BASIC SYSTEM PROCESSES IN THE MORE PRISTINE EXAMPLES OF THE DIFFERENT ECOSYSTEMS (A-21, C-28, N-13)

II.1 RIVER FLOW, SEDIMENT TRANSPORT & RIPARIAN VEGETATION RESEARCH, MONITORING, RESTORATION (C-6, C-21, C-22)

- Water flux: gauges on green and confluence
- Sand bar development and demise
- Beach formation and erosion
- Study impacts of tamarisk invasion
- Study ecology of tamarisk

II.1 VISITOR IMPACTS

- VISITOR IMPACTS TO ECOSYSTEMS: SOIL SURFACE DISTURBANCE (A-23, C-30, N-15)
  - Research on impacts, restoration techniques
  - Vegetative community structure (A-20, C-27, N-12)
  - Soil community structure
  - Soil physical/chemical characteristics: temperature, moisture, compaction, texture, etc.
  - Energy balance of soil communities (bacteria, fungi, nematodes, cyanobacteria, microarthropods, vascular plants): insolation, soil heating, respiration, productivity, energy flow (A-22, C-29, N-14)
  - Nutrient cycling: C, N, water
  - Key relationships between species (A-24, C-19, N-17)
  - Water dynamics: infiltration, evaporation, capillary and gravitational movement
  - Sediment fluxes: water and wind erosion
  - Albedo (A-21, C-28, N-13)

- VISITOR IMPACTS: WATER QUALITY MONITORING OF STREAMS/SPRINGS (A-13, C-27, N-11)
  - Invertebrate monitoring (C-22)
  - Human waste: nutrient input, disease
  - Research on impacts, restoration techniques
  - Impacts on bighorn
  - Inventory, monitor, research, maintain, restore

II.4 GIS (A-1, A-2, C-1, C-2, N-1, N-8)

Table 2. cont.

oInformation management
oVegetation (A-27, C-24), soils, geology, topography, hydrology, plant distribution, animal distribution, rare species, land use, land ownership, visitor use patterns, infrastructure, aerial/ortho-photos

II.5 ENDANGERED SPECIES: FISH POPULATION DYNAMICS (C-18, C-21)

oInventory, monitor, research, maintain, restore
oFish community structure (exotic and native)
oFood sources: phytoplankton, zooplankton, macroinvertebrates
oTamarisk impacts (see II.1)
oBackwater dynamics

II.6 SENSITIVE SPECIES: MEXICAN SPOTTED OWL, DESERT BIGHORN SHEEP, SOUTHWESTERN WILLOW FLYCATCHER, KACHINA DAISY, CANYONLANDS LOMATIUM, OTHER SENSITIVE SPECIES (A-25, C-18, C-20, N-19)

oInventory, monitor, research, maintain, restore (A-20, C-27, N-12)
oDistribution
oPopulation dynamics
oVisitor impacts
oCauses of population decline

II.7 EXOTIC PLANT CONTROL (A-29, C-24, N-21)

oInventory, monitor, research, control
oMethods of control

CRITICAL RESEARCH NEEDS: UNRANKED

IDENTIFY METHODS TO MAINTAIN ECOSYSTEMS AND IMPLEMENT: (A-27, C-24, N-20)

oVisitor management: protect structural & functional integrity of severely threatened aquatic & terrestrial systems (A-9, C-4, C-6)
- •Pristine area closures to prevent degradation before research is complete
- •Restrictions on use of springs, backwaters, critical wildlife and plant habitat (bighorn habitat, riparian areas such as Salt Creek, Courthouse Wash and White Canyon, bird nest sites, rare plant sites)
- •Designated trails and designated campsites to concentrate use patterns
- •Visitor education: programs stressing minimum impact techniques
- •Involve adjacent agencies' in planning processes
- •Other division involvement in resource management activities & planning
- •Boardwalks in sensitive areas such as Virginia Park
- •Develop plan for human waste disposal

oControl spread of exotic species (A-27, C-24, N-20)
oFencing of boundaries (A-27, C-8, C-24, N-20, N-22)
oGuide development of NPS infrastructure (A-6, A-14, A-30, C-10, N-6, N-7)

IDENTIFY RESTORATION METHODS AND RESTORE AQUATIC & TERRESTRIAL ECOSYSTEMS: ESTABLISH RESTORATION GOALS AND RESTORE SEVERELY DISTURBED OR RAPIDLY DEGRADING AREAS (A-28, C-26, N-20)

oRiver (C-21)

Table 2. cont.

- •Flow management
- •Remove unnatural levees
- •Exotic vegetation removal, planting native species
- •Manage visitor use

oSmall streams & springs (A-13, C-27, N-11)

- •Manage visitor use
- •Exclude vehicle traffic in Salt Creek (C-4)

oTerrestrial habitats

- •Establish restoration goals consistent with relict area structure and function
- •Actively restore current severe disturbances (construction sites) using seeding and transplants of native plants
- •Restore less disturbed habitats through management of timing and intensity of visitor use and non-mechanical restoration techniques

Table 2. cont.

MORE IMPORTANT RESEARCH NEEDS: UNRANKED

IDENTIFICATION & DEFINITION OF ECOSYSTEMS REPRESENTED IN SEUG (A-21, C-28, N-13)

- oAquatic & terrestrial ecosystems
- oAbiotic & biotic components

MAPPING OF SEUG ECOSYSTEMS (A-1, C-1, N-1)

- oCreate and maintain GIS
- oObtain, maintain, update hardware
- oSelect & train personnel
- oDefine themes & associated attribute files
- oAcquire and verify spatial information for:
  - •Vegetation (A-27, C-24)
  - •Soils
  - •Geology
  - •Topography
  - •Hydrology
  - •Rare species
  - •Animals
  - •Land use
  - •Land ownership
  - •Visitor use
  - •Infrastructure
  - •Aerial, ortho photoquads, video

IDENTIFY PRESENT AND FUTURE IMPACTS TO SEUG ECOSYSTEMS

- oVisitation impacts
  - •Trampling disturbance to soil crusts (A-23, C-30, N-15)
  - •Trampling disturbance to fossorial mammals (A-24, C-19, N-17)
  - •Bighorn disturbance by people presence (C-20)
  - •Water contamination by bathing (A-13, C-27, N-11)
  - •Disturbance of backwater nurseries (C-21)
  - •Impacts to riparian/terrestrial vegetation structure (A-27, C-24, N-20)
  - •Nesting bird disturbance (A-24, C-19, N-17)
  - •Vehicles (C-4)
  - •River use (C-6)
  - •Researchers (A-5, A-9, C-4)
- oWater flow & sediment effects (C-21)
- oExotic plants and animals (A-3, A-4, A-29, C-3, C-24, N-2, N-21)
- oInfrastructure development (A-6, A-14, A-30, C-10, N-6, N-7)
- oContaminants:
  - •Water
    - ·From outside park sources (A-7, C-5, N-4, N-5)
    - ·From uranium leaching (C-7)
  - •Air pollution (A-12, C-11, N-10)
- oEffects of global climate change (A-21, C-28, N-13)
- oDomestic livestock trespass (A-27, C-8)
- oIdentify populations/ecosystems at risk (A-21, C-28, N-13)
- oCauses of non-recovery from disturbance (A-28, C-26, N-20)
- oRestoration impacts (A-28, C-26, N-20)
- oRoads (A-8, A-10, C-5)
- oBiohazards (A-11, C-31, N-9)
- oIncompatible use on inholdings & adjacent lands (A-7, C-5, N-4, N-5)
- oNoise pollution (A-15, C-14)

Table 2. cont.

- Disruptions of natural night sky (A-16, C-15)

IDENTIFY PAST IMPACTS

- Grazing (A-19, C-13, N-4)
- Mining (C-7)

MEASURE THE CONDITION OF ECOSYSTEMS IN SEUG, ASSESSING HEALTH BASED ON INFORMATION WITH RELICT OR MORE PRISTINE AREAS (A-21, C-28, N-13)

- Develop baseline information using pristine areas and historical data
- Develop information to compare impacted areas to pristine baselines and historical data
- Measure aquatic structure & function
  - Quantify endangered fish (C-21)
  - Measure fish community structure (C-21)
  - Quantify invertebrates (A-22, C-22, C-29, N-14, N-16)
  - Quantify water quality (A-13, C-27, N-11)
  - Measure flow:
    - In springs
    - Effects on community structure
  - Study rare plant demographics etc. (A-25, C-18, N-19)
  - Quantify amphibians (A-24, C-19, N-17)
  - Measure sedimentation processes (C-21)
  - Determine natural disturbance regimes (C-21)
  - Quantify exotics if present (C-21)
- Measure terrestrial structure & function (determine species composition, abundance and physical structure for:)
  - Characterize vegetation community structure (A-20, C-27, N-12)
  - Characterize soil community structure (A-23, C-30, N-15)
  - Characterize soil physical/chemical characteristics (A-23, C-30, N-15)
  - Characterize nutrient cycling for: (A-23, C-30, N-15)
    - Carbon
    - Nitrogen
    - Water
  - Quantify energy balance (A-23, C-30, N-15)
  - Determine key relationships between species (A-24, C-19, N-17)
  - Quantify climatic factors (A-20, C-27, N-12)
  - Quantify aboveground invertebrates (A-22, C-29, N-14)
  - Study distributions & population ecology of endangered species (A-25, C-18, N-19)
  - Monitor vegetation changes (A-20, C-27, N-12)
  - Study mammals: (A-24, C-19, N-17)
    - Large:
      - Desert bighorn sheep (C-18, C-20)
      - Deer
    - Small: (A-20, C-27, N-12, N-16)
      - Bats (A-20, A-24, C-19, C-27, N-16, N-17)
  - Study reptiles (A-24, C-19, N-17, N-18)
  - Study birds:
    - Large: (A-24, C-19, N-17)
      - Peregrine falcons
      - Mexican spotted owls
    - Small (C-23)
  - Determine natural disturbance regimes (C-25, N-24)

INFORMATION NEEDS OF ECOSYSTEMS: IDENTIFY & MEASURE CONDITIONS
CHARACTERIZE PARK ECOSYSTEMS' RESISTANCE TO SOIL SURFACE DISTURBANCE

Table 2. cont.

(A-23, C-30, N-15)

oWater pollutant monitoring of streams, springs, river (park, NAWQA)
(A-13, C-27, N-11)
- •Organics
  - ·Petrochemical
  - ·Human waste
- •Metals
- •Salts
  - ·Selenium in fish and sediments
  - ·Electrical conductivity

oFlow rates from springs and seeps

oNeotropical migrants (C-23)
oAbove-ground invertebrates (A-22, C-19, N-14, N-16)
oAmphibians: population dynamics, distribution (A-13, C-27, N-11)
oDetritus: aquatic and terrestrial (A-21, C-28, N-13)

<u>RESTORE MODERATELY DEGRADING ECOSYSTEMS AND IDENTIFY METHODS TO MAINTAIN SYSTEMS ONCE RESTORED</u> (A-28, C-26, N-20)

oAquatic & riparian habitats
oSmall streams & springs
- •Exclude trespass cattle with boundary fence (A-27, N-20, C-24)
- •Restore vegetative cover of watersheds
- •Exclude vehicle traffic in moderately degrading riparian zones (C-4)
- •Exotic plant control (A-29, C-24, N-21)

Table 2. cont.

IMPORTANT RESEARCH NEEDS: UNRANKED

IDENTIFY INTERACTIONS AMONG ECOSYSTEMS (e.g. ENERGY & NUTRIENT FLUXES) (A-21, C-28, N-13)

- oMeasure ecosystem fluxes
- oMeasure sediment fluxes:
  - •Terrestrial--wind and water erosion
  - •Aquatic
- oQuantify water movement & storage
  - •Continue current precipitation measurements
  - •Expand precipitation measurement network
  - •Add storage gauges at:
    - ·Selected springs
    - ·Green river
    - ·Below confluence
  - •Measure soil moisture, infiltration, ground water
  - •Get USGS to add NAWQA station below confluence
- oMeasure chemical fluxes
- oMeasure organic fluxes
- oMeasure petrochemicals:
  - •In springs
  - •In fish
- oMeasure human waste (bacteria)
- oMeasure organochlorides
- oAnalyze Peregrine egg shells for organochlorides (A-25, C-18)
- oMeasure metal fluxes through:
  - •General fish survey
  - •Water quality baseline
- oMeasure salt fluxes:
  - •Selenium
  - •Fish
  - •Sediments
  - •Electrical conductivity
  - •Others
- oMeasure radiation in springs
- oMonitor atmospheric pollutants (A-12, C-11, N-10)
- oMeasure bacteria in springs (A-13, C-27, N-11)

- oDelineate riverine and terrestrial corridors, barriers, ecotones (abiotic & biotic factors) (A-1, C-1, N-1)
  - •Rivers
  - •Geologic features
  - •Invertebrates
  - •Fish
  - •Mammals
  - •Birds
  - •Vegetation
  - •Recreational activities
  - •Park infrastructure
  - •Atmospheric patterns
  - •Air flow patterns

- oCharacterize ecotones (A-21, C-28, N-13)
  - •Identify types of ecotones
  - •Determine extent of ecotones
  - •Rank importance of ecotones
  - •Measure structure & function of ecotones (see identify ecosystems)

Table 2. cont.

INFORMATION NEEDS OF ECOSYSTEMS: IDENTIFY, MEASURE CONDITIONS, MAP, STUDY INTERACTIONS BETWEEN (A-21, C-28, N-13)

- Characterize according to factors under soil surface disturbance
- Water quality monitoring program by park of river, springs, streams (A-13, A-20, C-27, N-11)
- Study climatic factors (A-20, C-27, N-12)
- Determine distribution & population dynamics: (A-24, A-25, C-18, C-19, N-17, N-19)
  - Other mammals (large and small)
  - Breeding birds, Peregrines, bald eagles, Mexican spotted owls
  - Reptiles
  - Aquatic rare plants: e.g. Rydberg thistle Cirsium rydbergii
- Ground water: contaminants, depth, fluctuations (A-13, C-27, N-11)
- Water flux (A-13, C-27, N-11)
- Pothole water warming (A-13, C-27, N-11)
- Trophic dynamics, predator studies (C-19)
- Quantify ecosystem productivity (A-21, C-28, N-13)
- Determine potential of oil and gas drilling contamination of aquifers (A-11, C-31, N-9)
- Be prepared to assess impacts of petrochemical spills in water

MAINTAIN ECOSYSTEMS: VISITOR MANAGEMENT (PROTECT STRUCTURAL & FUNCTIONAL INTEGRITY OF RELATIVELY STABLE AQUATIC & TERRESTRIAL SYSTEMS)

RESTORE DEGRADED, BUT STABLE, ECOSYSTEMS:

- Aquatic & riparian habitats
- River (C-21)
  - Transplants, augmentation of native fish
  - Removal of exotic fish
- Terrestrial
  - Actively restore past severe disturbances (Devil's Lane, etc.) using seeding and transplants of native plants (A-28, C-26, N-20)

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APPENDIX I. SEUG RESOURCE MANAGEMENT PLAN PROJECT STATEMENTS

RMP PROJECT STATEMENTS

ARCHES

ADMINISTRATION
- ARCH-N-001 Geographic Information System
- ARCH-N-002 Remote Sensing Needs
- ARCH-N-003 Integrated Pest Management Plan and Program
- ARCH-N-004 Museum Integrated Pest Management
- ARCH-N-005 Backcountry Management
- ARCH-N-006 Utility Corridor
- ARCH-N-007 External Issues
- ARCH-N-008 External Threats - Highway Development
- ARCH-N-009 Visitor Experience and Resource Management Plan
- ARCH-N-010 Floodplain Assessment - Delicate Arch Road
- ARCH-N-011 Hazardous Spills Management Response Plan

PHYSICAL RESOURCES
- ARCH-N-012 Air Resources Management
- ARCH-N-013 Water Resource Management - Natural Water Sources
- ARCH-N-014 Water Resource Management - Developed Water Sources
- ARCH-N-015 Natural Silence
- ARCH-N-016 Night Sky
- ARCH-N-017 Paleontology
- ARCH-N-018 Quaternary Resources
- ARCH-N-019 Grazing History

ECOSYSTEM ASSESSMENT
- ARCH-N-020 Inventory and Monitoring
- ARCH-N-021 Ecosystem Health Assessment
- ARCH-N-022 Invertebrates and Soil Microflora
- ARCH-N-023 Cyanobacterial-Lichen-Moss Soil Crusts

WILDLIFE RESOURCES
- ARCH-N-024 Wildlife Resources
- ARCH-N-025 Threatened, Endangered and Sensitive Species

VEGETATION
- ARCH-N-026 Fire Management
- ARCH-N-027 Vegetation Management
- ARCH-N-028 Vegetation Reclamation
- ARCH-N-029 Exotic Plant Control and Management

CONSUMPTIVE USE
- ARCH-N-030 Borrow Materials Management

CANYONLANDS

ADMINISTRATION
- CANY-N-001 Geographic Information System
- CANY-N-002 Remote Sensing Needs
- CANY-N-003 Integrated Pest Management Plan and Program
- CANY-N-004 Backcountry Management
- CANY-N-005 External Issues
- CANY-N-006 River Management
- CANY-N-007 Inventory Old Mines and Abandoned Mineral Lands
- CANY-N-008 Trespass Livestock/Burro Management
- CANY-N-009 Plug and Abandon Six Water Wells
- CANY-N-010 Borrow Materials Management

PHYSICAL RESOURCES
- CANY-N-011 Air Resources Management
- CANY-N-012 Water Resources Management
- CANY-N-013 Grazing History
- CANY-N-014 Natural Silence
- CANY-N-015 Night Sky

CANY-N-016 Paleontology Resources
CANY-N-017 Quaternary Resources

ANIMAL RESOURCES

CANY-N-018 Threatened, Endangered and Sensitive Species
CANY-N-019 Wildlife Resources
CANY-N-020 Desert Bighorn Sheep
CANY-N-021 Fisheries Management
CANY-N-022 Benthic Macroinvertebrate Inventory
CANY-N-023 Neotropical Migrant Monitoring

VEGETATION MANAGEMENT

CANY-N-024 Vegetation Management
CANY-N-025 Fire Management
CANY-N-026 Vegetation Reclamation
CANY-N-027 Inventory and Monitoring
CANY-N-028 Ecosystem Health Assessment
CANY-N-029 Invertebrates and Soil Microflora
CANY-N-030 Cyanobacterial-Lichen-Moss Soil Crusts

NATURAL BRIDGES

ADMINISTRATION

NABR-N-001 Geographic Information System
NABR-N-002 Integrated Pest Management
NABR-N-003 External Issues - Monitoring and Assessment
NABR-N-004 External Issues - Grazing Impacts
NABR-N-005 External Issues - Oil and Gas Development
NABR-N-006 Water Systems Management
NABR-N-007 Consumptive Use of Borrow Materials
NABR-N-008 Remote Sensing Needs
NABR-N-009 Hazardous Materials Spill Response Plan

PHYSICAL RESOURCES

NABR-N-010 Air Resources Program Management
NABR-N-011 Surface Water Resource Management

ECOSYSTEM ASSESSMENT

NABR-N-012 Inventory and Monitoring Program Management
NABR-N-013 Ecosystem Health Assessment
NABR-N-014 Invertebrates and Soil Microflora
NABR-N-015 Cyanobacterial-Lichen-Moss Soil Crusts
NABR-N-016 Inventory and Monitoring - Unfunded Needs

WILDLIFE RESOURCES

NABR-N-017 Wildlife Resources Management
NABR-N-018 Midget Faded Rattlesnake
NABR-N-019 Threatened, Endangered and Sensitive Species

VEGETATION MANAGEMENT

NABR-N-020 Vegetation Management Program
NABR-N-021 Vegetation Management - Exotic Plant Control
NABR-N-022 Vegetation Management - Livestock Fencing Needs
NABR-N-023 Vegetation Management - Pinyon/Juniper Research
NABR-N-024 Fire Management

QUATERNARY RESOURCES

NABR-N-025 Quaternary Resources

APPENDIX II. PAST RESEARCH IN SEUG

RESEARCH PROJECTS CONDUCTED IN SEUG 1989-1993

PRINCIPAL INVESTIGATOR	PROJECT TITLE
AGENBROAD, LARRY	•QUATERNARY STUDIES AT CANYONLANDS AND GLEN CANYON
ALLPHIN, LOREEN	•DEMOGRAPHY AND REPRODUCTIVE BIOLOGY OF ERIGERON KACHINENSIS
ANTONELLINI, MARCO	•STRUCTURAL AND FLUID FLOW PROPERTIES OF DEFORMATION BANDS IN POROUS SANDSTONES
ARMSTRONG, DAVID M.	•MAMMALS OF CANYONLANDS NATIONAL PARK
BELNAP, JAYNE	•EFFECTS OF AIR POLLUTION ON CRYPTOGAMIC CRUSTS
BELNAP, JAYNE	•EFFECTS OF TRAMPLING ON SOIL SURFACE AND BELOW-GROUND RESOURCES
BICE, DAVID	•ORIGINS OF THE UPHEAVAL DOME
BOGAN, MICHAEL	•BIOLOGICAL SURVEYS ON PUBLIC LANDS
BOUBIN, MICHAEL ALLAN	•ELEPHANT CANYON FORMATION
CARTWRIGHT, JOSEPH	•RECONNAISSANCE ON FAULTING PATTERNS
CLARK, ROGER	•MAPPING LITHOLOGIES AND SOILS USING LEAST-SQUARES BAND MAPPING AND AVIRIS DATA OVER UPHEAVAL DOME AND ARCHES NATIONAL PARK.
COX, CHRISTENA M.	•LATE PALEOZOIC EVOLUTION OF THE PARADOX BASIN AS REFLECTED IN THE PENNSYLVANIAN CARBONATE SECTION
CRUIKSHANK, KENNETH	•ANALYSIS OF MINOR FRACTURES ASSOCIATED WITH JOINTS AND FAULTED JOINTS
DEAN, JEFFREY S.	•DENDROCLIMATIC CHARACTERIZATION OF SOUTHWESTERN PALEOCLIMATE DURING THE LAST 2000 YEARS
DODDS, WALTER	•DIATOMS OF EPHEMERAL POOLS AS AIR QUALITY INDICATORS
DOTT, CYNTHIA	•INTERACTIONS OF HUMAN LAND-USE AND NATURAL DISTURBANCE REGIMES IN CHARACTERIZING PLANT COMMUNITIES AROUND CEDAR MESA
FLEMING, RICHARD	•THREATENED, ENDANGERED, RARE PLANT SPECIES
GLENN, JAMES	•RATTLESNAKE VENOM INVESTIGATION --S.E. UTAH
GRAHAM, TIM	•BLACKBRUSH SEEDLING ESTABLISHMENT
GRAHAM, TIM	•ECOLOGY OF POTHOLES ON THE COLORADO PLATEAU
GRAHAM, TIM	•ECOLOGY OF RATTLESNAKES IN DISTURBED ENVIRONMENTS
GRAHAM, TIM	•EFFECTIVENESS OF THE HERBICIDE GARLON 3A ON TAMARISK
GRAHAM, TIM	•INTERACTIONS BETWEEN FRAXINUS ANOMALA (SINGLE-LEAF ASH) AND TROPIDOSTEPTES SPP. (HEMIPTERA:MIRIDAE)
HATHAWAY, LISA	•OBSERVATIONS OF WINTERING BALD EAGLES FROM THE CATARACT CANYON RIM, CANYONLANDS NATIONAL PARK
HEIL, KEN	•COMPOSITION, DISTRIBUTION, RELATIVE ABUNDANCE, AND HABITAT REQUIREMENTS OF ENDANGERED, THREATENED, AND RARE PLANT SPECIES IN SOUTHEAST UTAH GROUP OF NATIONAL PARKS
HOHMANN, GERALD	•MAPPING THE DEPTH OF A CANYONLANDS GRABEN WITH SEISIMIC AND ELECTROMAGNETIC METHODS
HUFFMAN, CURTIS	•U.S. GEOLOGICAL SURVEY EVOLUTION OF SEDIMENTARY BASINS PARADOX BASIN PROJECT, UTAH AND COLORADO
HUGHES, HARRISON	•BLACKBRUSH REGENERATION
JOHNSON, DAVID W.	•GENIC VARIATION IN THE CANYON MOUSE, PEROMYSCUS CRINITUS
JOURNETT, ALAN R. P.	•VEGETATION PATTERNS IN THREE GRASSLANDS RELEASED FROM GRAZING PRESSURE; HABITAT USE BY SMALL MAMMALS IN AND AROUND THE HANGING GARDEN COMMUNITIES; BIRD SPECIES DIVERSITY IN THE P/J COMMUNITY
KEPNER, WILLIAM G.	•ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM
KONDRETIEFF, BORIS	•INVENTORY OF ARTHROPODS IN CANYONLANDS

LEWIS, EDWIN	•DETERMINATION OF PARTICULATE ORGANIC COMPOUNDS AT ISLAND IN THE SKY VISITOR CENTER IN CANYONLANDS
LINNEMANN, TIMOTHY C.	•DESERT BIGHORN MATING BEHAVIOR AND MANAGEMENT IN THE NEEDLES DISTRICT OF CANYONLANDS NATIONAL PARK
LOWE, DON	•ORIGINS OF UPHEAVAL DOME
LUCAS, SPENCER	•TRIASSIC PALEONTOLOGY IN THE UPHEAVAL DOME AREA, CANYONLANDS
MAY, CATHLEEN	•PALEOECOLOGY OF TERRESTRIAL ECOSYSTEMS AT THE TRIASSIC-JURASSIC BOUNDARY
MEAD, JAMES	•BISON ALCOVE PACKRAT MIDDEN STUDY
MILLER, GARY	•DISPERSAL PATTERN OF THE OBLIGATE BURROWING WOLF SPIDER GEOLYCOSA RAFAELENA: ADAPTATIONS FOR THE DESERT ENVIRONMENT
MITCHELL, SANDRA	•MAN'S EFFECTS ON AQUATIC AND RIPARIAN ORGANISMS IN THE CANYONS OF CANYONLANDS AND ARCHES NP AND NATURAL BRIDGES NM
MURDOCH, ANDREW	•GEOLOGY OF SALT VALLEY ANTICLINE
MURRAY, ROY	•POPULATION GENETICS AND BIOGEOGRAPHY OF THE CANYON TREE FROG
McADA, CHUCK	•REPRODUCTIVE SUCCESS OF THE ENDANGERED COLORADO SQUAWFISH (PTYCHOCHEILUS LUCIUS) AND SYMPATRIC, INTRODUCED FISHES IN THE COLORADO RIVER
McADA, CHUCK	•DISTRIBUTION OF LARVAL FISHES IN THE COLORADO RIVER
MacDONALD, JOHN	•AQUATIC INSECTS, DIPTERA (FLIES)
NASH, WILLIAM	•CHEMISTRY AND VARIATIONS IN VOLCANIC ASH UNITS
NITTMAN, SHAWN	•A PALEOECOLOGICAL RECONSTRUCTION OF ANDERSON GULCH BASED ON FOSSIL INVERTEBRATES
OSMUNDSON, DOUG	•EVALUATION OF THE CURRENT STATUS OF THE COLORADO SQUAWFISH IN THE; COLORADO RIVER
PENDLETON, BURTON	•REGENERATION BIOLOGY OF BLACKBRUSH (COLEOGYNE RAMOSISSIMA)
PIERCE, BENJAMIN A.	•ACID SENSITIVITY OF EGGS AND LARVAE OF TWO POTHOLE-DWELLING AMPHIBIANS FROM UTAH
RAMSEY, JAMES	•MOLECULAR SYSTEMATIC SURVEY OF THE SECTION ERYTHRANTHE OF THE GENUS MIMULUS (SCROPHULARIACEAE)
RAWLINS, DAVID	•CATARACT CANYON FRACTURE STUDY
ROSENSTOCK, STEVE	•A SURVEY OF SMALL MAMMALS AND VEGETATIVE CHARACTERISTICS IN GRASSLANDS OF NORTH FLAT, MAZE DISTRICT, CANYONLANDS NATIONAL PARK, UTAH
SCHULTZ-ELA, DAN	•GEOLOGIC RESEARCH IN UPHEAVAL DOME
SHARPE, SAXON	•IDENTIFICATION AND ANALYSIS OF THE PLEISTOCENE AND HOLOCENE FLORAL AND FAUNAL COMMUNITIES
STANTON, NANCY L.	•BIOGEOGRAPHY OF PLANTS AND INVERTEBRATES IN HANGING GARDENS OF THE COLORADO PLATEAU
STARNES, WAYNE	•GILA TAXONOMY
STEVENS, LARRY	•BENTHIC MACROINVERTEBRATE SAMPLING IN THE GREEN AND COLORADO RIVERS, CANYONLANDS NATIONAL PARK
SWEZEY, CHRISTOPHER S.	•INVESTIGATION OF THE JURASSIC J-2 EROSIONAL SURFACE OF THE WESTERN INTERIOR OF THE UNITED STATES--CONDITIONS OF FORMATION AND IMPLICATIONS FOR BASIN TECTONICS
VANPELT, NICHOLAS	•SURVEY AND ANALYSIS OF RELICT VEGETATION SITES WITHIN NATIONAL PARK SYSTEM UNITS OF THE COLORADO PLATEAU
VAN RIPER III, CHARLES	•HABITAT ECOLOGY OF MEXICAN SPOTTED OWLS IN CANYONLANDS TERRAIN
WEBB, ROBERT	•PHOTODOCUMENTATION OF CATARACT CANYON FOR COMPARISON TO PHOTOS TAKEN ON HISTORICAL EXPEDITIONS

WEBER, DARRYL	•DIE-OFF OF UTAH JUNIPER, NATURAL BRIDGES NATIONAL MONUMENT
WICK, ED	•SAMPLING FOR RAZORBACK SUCKER PRODUCTION, SPRING 1993
WILLEY, DAVID	•HOME-RANGE CHARACTERISTICS OF MEXICAN SPOTTED OWLS IN THE CANYONLANDS GEOGRAPHIC PROVINCE
WILLIAMS, ROBERT G.	•FISHERIES BIOLOGY AND RAFTING--THE CATARACT CANYON FISHERIES STUDIES
WINDHAM, MICHAEL	•NEW SPECIES OF NORTH AMERICAN CYSTOPTERIS AND POLYPODIUM WITH COMMENTS ON THEIR RETICULATE RELATIONSHIPS

APPENDIX III. PROJECT STATEMENTS FOR TOP PRIORITY CRITICAL RESEARCH NEEDS

ECOSYSTEM CHARACTERIZATION:

CHARACTERIZATION OF MAJOR ECOSYSTEMS IN SEUG
Priority II.1

STATEMENT OF PROBLEM

The Park Service has a mandate to manage and protect the lands and systems entrusted to it in a manner that maintains these systems, unimpaired, for future generations. There are many compelling reasons for us to take this mandate to heart, especially in arid and semi-arid regions. Altered systems' functioning in deserts may affect regional precipitation patterns, with disturbed lands receiving less moisture through increased albedo, decreased infiltration and reduced evapotranspiration (Postel 1989). Disturbing arid landscapes results in increased sediment movement by wind and water leading to loss of topsoil, degradation of watersheds and downstream aquatic systems, and the alteration of biotic communities (Postel 1989; A. Pope, J. Belnap, unpublished data). Irretrievable nutrient loss has been documented in these disturbed lands, as well as increasing soil temperatures that retard accumulation of organic nitrogen (N) in the soil. Biodiversity at the species, process and system levels is being lost (Schlesinger et al. 1990). For these reasons, it is imperative that we address and aid the recovery of these disturbed systems.

Much of the land set aside for parks has already been disturbed, with accompanying moderate to severe disruption of the ecosystems involved. Construction activity within parks is constantly creating additional disturbances. In the past, the Park Service has either attempted revegetation of the disturbed areas or left them to recover on their own. Unfortunately, the return of stable, functioning communities is not always that simple, especially in arid and semi-arid regions. Simple replacement of plant materials does not necessarily create sustainable systems. Lack of sustainability results in communities that are invaded by undesirable species, suffer loss of productivity, lack key biotic interactions, or have continued loss of nutrients. Because of this, revegetation efforts often require continual inputs of time and money.

Areas left to recover on their own have generally not done so (Schlesinger et al. 1990, Young and Tipton 1990, Whisenant 1990, Elton 1977, Moffatt 1989, Ehrlich and Mooney 1983). Semi-arid and arid regions appear especially susceptible to this non-recovery phenomena, as can be seen vividly in parks throughout the Colorado Plateau.

Deserts are very different from other ecosystems in being autogenic, with the same species often being both the colonizers and climax dominants. Harshness and unpredictability of the environment appears to prevent organisms from significantly altering sites they occupy. Germination and establishment are problematic. Time to a climax community is accompanied by little change in the physiognomy or species of the community (MacMahon 1980). Light is not limiting, while water is, and below-ground processes become relatively more important in desert systems when contrasted with more mesic sites (Allen 1987). For these reasons, deserts need their own models for succession and restoration. These factors may also make succession a more easily dissected process in deserts, as fewer factors are involved (MacMahon 1987).

Development of a model for desert restoration and succession requires that undisturbed areas be studied and basic ecosystem processes characterized (e.g., nutrient cycling and distribution, vesicular-arbuscular mycorrhizae (VAM) biomass and activity, niche quantification for dominant vascular plant species, community floristics, faunal composition and soil features) to provide us with a picture of what sustainable ecosystems should look and act like. With this picture, we can then establish restoration goals, and compare and assess recovery of systems previously and currently disturbed in park units.

The Southeast Utah Group of parks are uniquely suited for such an effort.

Undisturbed areas have been identified in these park units that represent five of the major habitat types (pinyon pine-juniper, pinyon-pine-juniper-sage, grassland, blackbrush and riparian communities) found on the Colorado Plateau. Unrecovered areas, some disturbed over 25 years ago, exist in these same habitat types. Much information exists concerning establishment requirements for the dominant vascular plant species, compiled by mining companies, the Soil Conservation Service, the Forest Service and the Bureau of Land Management. Research on (VAM) associations and the re-establishment of the cyanobacterial-lichen soil crusts has been done in this region. Information is also available on geology and climate, and the necessary soil data are easily collected. By combining all this information with that obtained from studies of the undisturbed areas, much can be done to alleviate the problem of continued input to, or non-recovery of, disturbed systems. By attempting to restore the major components and processes of the pre-disturbance system as seen in the studied areas, restored systems will have a much better chance of being sustainable.

Restoration of disturbed lands is management of ecological principles for a specific purpose. To this end, we need to understand the ecological principles we are attempting to manipulate; the greater our understanding, the better able we will be to achieve the desired end. This end may differ: it may be restoration of the disturbed area to represent the natural, adjacent area, or to represent some other purpose, such as historical scenes. Whatever the end, effective management--considering economics, implementation time, and desirable results--is dependent on the understanding of these ecological principles (MacMahon 1987).

RECOMMENDED ACTION

Basic ecosystem functioning in undisturbed representatives of major habitat types in the Southeast Utah Group needs to be characterized. It is proposed that this process begin with the three major habitat types found in the parks: grassland, blackbrush-dominated mixed shrub and low-productivity pinyon-juniper. These three community types are extremely common both in the Southeast Utah Group of parks and on the Colorado Plateau, comprising well over 75% of the Southeast Utah Group, and over 65% (more than two million acres) of lands within Colorado Plateau park units. Pristine areas of these community types have been located and cataloged by the Nature Conservancy (in cooperation with NPS), and representatives of the three major habitat types are found in Canyonlands. Areas chosen for this study are both accessible and representative of the desired habitat type, and have already had some initial research done in them. Past disturbances of varying ages and stages of recovery in these same habitat types can be found adjacent to these undisturbed areas, offering an excellent opportunity for comparative studies.

Below are listed the components of the model that will be developed for each major habitat type. The first four categories (site climatic, geologic, soil and disturbance factors) require information that is quickly and easily obtainable. The last three categories will require longer-term research to obtain the necessary information. There are no priorities within these last three categories; what is done when will depend on funding and researcher availability.

MODEL COMPONENTS FOR RELICT AND PREVIOUSLY DISTURBED AREAS

A. SITE CLIMATIC FACTORS:
- Temperatures
- Frost-free period
- Precipitation: amount, timing, intensity
- Wind: direction, season, intensity
- Evapotranspiration

(Data are available for yearly, seasonally and monthly background levels; spatial and temporal variability; means; extremes; not intensities)

B. SITE GEOLOGIC FACTORS
- Regional
- Physiography
- Elevation
- Drainage/ topography
- Hydrology (infiltration, sediment production, runoff)
- Weathering
- Strata: chemical and physical analysis

(Data available except site specific hydrology and strata chemical analyses)

C. SITE SOIL FACTORS (NON-BIOLOGICAL)
- Classification
- Profile or depth analysis
- Habitat type/ range site/ vegetation type
- Texture: clay/sand
- Water-holding capacity
- Infiltration rate
- Stone content
- Bulk density
- Organic matter
- pH
- Salt-related properties
  - Electrical conductivity
  - Sodium adsorption ratio
  - Soluble cations
  - Soluble anions
- Heavy metals
- Availability of plant macronutrients (N, P, K)
- Availability of plant micronutrients (e.g. Zn, Cu)
- Soil moisture levels at different depths, times
- Carbon/nitrogen ratios
- Carbon/phosphorus ratios
- Wind erosion potential

D. SITE DISTURBANCE FACTORS: Extent and intensity of past and present disturbances
- Type
- Intensity
- Frequency
- Shape of area (edge area ratio)
- Distance for dispersal

E. SITE NUTRIENT CYCLING AND DISTRIBUTION
- Patterns of distribution for major nutrients, overall cation and anion levels throughout habitat
- Nitrogen budgets: source and sinks for all N forms
- Phosphorus budget

F. KEY SPECIES' NICHE QUANTIFICATION

1. Dominant vascular plants:
   - Seed bank
     - Quantity
     - Species
     - Germination requirements
   - Pollinators
   - Dispersal mechanisms
   - Herbivores, granivores
   - Mycorrhizal associations (obligate/facultative)
   - Productivity (above-ground and below-ground)
   - Water needs/ Drought tolerance
   - Roots: density, distribution
   - Establishment and survival requirements
2. Invertebrate and vertebrate fauna (above and below-ground):
   - Inventory
   - Functional group designations (pollinators, dispersers, decomposers, herbivores, granivores, etc.)
   - Biomass
   - Dispersal mechanisms
3. Soil microflora
   a. Cyanobacterial-lichen crusts:
      - Biomass
      - Structure
      - Role in soil stabilization
      - Nutrient relations, establishment and success of vascular plants
      - Dispersal
      - Establishment and survival
   b. Mycorrhizal associations:
      - Inventory
      - Biomass
      - Activity levels
      - Role in plant establishment and success
      - Dispersal
      - Establishment and survival

G. SPATIAL AND TEMPORAL ORGANIZATION OF COMMUNITY: plant and animal community architecture, spatial and temporal patterns energy flows; key relationships between species

Community proportions and spacing: indices of richness, abundance, evenness, patchiness, commonness and rarity.

Architecture: vertical and horizontal, seasonal development, persistence and variety of above-and below-ground parts, drop zone for or organic matter, litter, spores, seeds, cover for spiders and other inverts, small mammals

Energy flows: energetic relationships between species

Key relationships: are any species pivotal in ecosystem functioning?

FUNDING

$300,000 per habitat type

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ECOSYSTEM CHARACTERIZATION:

MONITORING OF MAMMALS IN SEUG
Priority: II.1

STATEMENT OF PROBLEM

Summits of several buttes and mesas and isolated canyons and parks (many identified by The Nature Conservancy) are ideal sites for examining ecological systems for baseline structure and function. SEUG should examine populations in unique, limited and/or undisturbed habitats such as hanging gardens (such as the work currently being conducted by Nancy Stanton et al., University of Wyoming), stands of relict vegetation (Douglas-fir, ponderosa pine and aspen); springs, seeps and creeks; mesa and butte tops. These will provide some reference for comparison with disturbed areas and will document status before the areas are affected by humans more than they already have been.

The use of buttes and mesas is not only valuable because of the undisturbed nature, but also because the faunas are simpler for mammals and reptiles. Valuable studies of demography, reproductive rate, offspring mortality, home range, dispersal, competition, predation, herbivory and genetics should be conducted on buttes. A long-term study of several sites through time would clarify many ecological questions about community structure and the roles of particular species in a community. This same approach may be used for other guilds of animals as well, and can be approached on different levels ranging from individual species to ecosystem.

Isolated buttes and mesas may be used to study how small rodent communities function and are structured in a simpler community, and to determine what their influence on ecosystems are. Butte systems should be compared to surrounding systems relative to small mammals and other groups. The question of whether depauperate mammal, reptile and/or ant communities on buttes result in subtle differences between vegetation communities or other aspects of ecosystems on and off buttes should be addressed. Are butte small mammal communities dictated by vegetation communities or just access constraints?

RECOMMENDED ACTION

SEUG should continue to monitor populations in paired disturbed/undisturbed habitats. Couple these studies with analysis of soil structure/soil flora and fauna. Can changes in soil characteristics and/or plant production be correlated with mammalian diversity/production? Unfortunately, much small mammal trapping activity disturbs the soil in the same way as hikers and off-road vehicles--once undisturbed areas are disturbed by the researcher. Sampling transects that minimize disturbance could be used in some habitats, e.g. areas with hiking trails or adjacent slickrock.

Trapping schemes should be established in relict communities in as many vegetation types as are available and in disturbed areas of corresponding vegetation types. Trapping inventories should be conducted during different seasons of the year. An alternative trapping design will be necessary for hanging garden communities. This effort will contribute to the characterization of SEUG ecosystems. Sampling designs should be implemented with the goal of assessment of pristine community ecology on an ecosystem (not single taxonomic group) level.

Proposals will need to be detailed to address the many other research issues regarding small mammals.

ECOSYSTEM CHARACTERIZATION:

COMPARISON OF INVERTEBRATE COMMUNITIES OF PRISTINE AND PREVIOUSLY DISTURBED (E.G. GRAZED) SYSTEMS: IMPACT ON ECOSYSTEM FUNCTIONING OF DIFFERENCES IN THESE COMMUNITIES
Priority: II.1

STATEMENT OF PROBLEM

Background information: Invertebrates are important in a number of critical ecosystem processes (e.g., pollination, decomposition, herbivory, etc.).

Objectives:

1. To describe invertebrate communities in pristine relict environments and contrast with invertebrate communities in previously grazed, but now relatively undisturbed systems, and currently heavily visited systems.

2. To compare guilds and functional groups between pristine and disturbed sites.

3. To measure critical levels of ecosystem processes (e.g., decomposition rates, primary productivity, nutrient cycling, etc.) in the two areas.

4. To correlate differences in ecosystem processes with differences in invertebrate communities.

5. To experimentally remove, in pristine areas, groups of invertebrates postulated to drive selected processes and monitor changes in ecosystem structure and function.

6. To experimentally add invertebrate groups suspected to be important and monitor changes in disturbed areas.

RIVER FLOWS, SEDIMENT TRANSPORT AND RIPARIAN VEGETATION:

STREAMFLOW AND RIPARIAN VEGETATION IN THE GREEN AND COLORADO RIVERS, SEUG Priority II.1

STATEMENT OF PROBLEM

River flows throughout the Colorado River System are regulated by the operation of the Colorado River reservoir system. Flows of both the Green and Colorado Rivers in Canyonlands National Park (CANY) have been modified by the operation of upstream reservoirs. However, the degree to which historic flow patterns have been modified by river regulation is less than exists for other river reaches in other Colorado River parks. For example, Colorado River flows through Grand Canyon National Park, and Green River flows through Lodore Canyon in Dinosaur National Monument are defined almost exclusively by the operation of upstream reservoirs. In contrast, the amount of reservoir storage compared to total basin runoff is substantially less for the river reaches in Canyonlands.

There has been little investigation into the interactions between river flows, and flow-dependent processes and conditions along the Green and Colorado Rivers in Canyonlands. Furthermore, there is little quantitative documentation of the changes in aquatic and riparian ecosystems induced by the construction and operation of upstream water projects. There is a critical need to understand how river resource conditions in Canyonlands are influenced by river regulation. Furthermore, by understanding the interactions between flows and flow-dependent conditions and processes in Canyonlands, valuable contributions will be made towards understanding issues related to river regulation in other, more-impacted, reaches of the Colorado River system. Research and monitoring of flow-dependent processes and conditions will provide the National Park Service an enhanced scientific basis for interacting in river planning and environmental assessment programs, such as the Bureau of Reclamation's Colorado River Annual Operating Planning Work Group.

The largest body of research on the subject of flow-resource interactions along the Colorado River has stemmed from the Glen Canyon Environmental Studies (GCES) Program, which was established in 1980 to evaluate the effects of the operation of Glen Canyon Dam on downstream resources in Grand Canyon. Research sponsored by the GCES has documented numerous responses of downstream resources to altered flows. Reductions in sediment loads, reduced annual flood magnitudes, changes in water temperature and imposition of daily flow fluctuations related to hydro-power production have combined to induce changes in downstream aquatic and riparian conditions. For example, aquatic vegetation and macroinvertebrate communities have been dramatically changed. This has favored introduced fishes over native species. Riparian vegetation has encroached into the pre-dam annual floodplain and species composition has changed. Habitat features such as beaches and backwaters, which are dependent upon flow-related sedimentation processes, have been dramatically altered, both in terms of abundance and condition. Finally, river-dependent amenities such as recreation and cultural resources are affected by changes in flow regime.

Other related studies are also occurring elsewhere in the basin. Reoperation of Flaming Gorge in response to a section 7 Biological Opinion on endangered fish began in 1992, and is being accompanied by a five-year period of test releases to permit additional study on the effects of flow alterations on resources. A decision to prepare an Environmental Impact Statement on the effects of operations at the Aspinal Unit on the Gunnison River also is being accompanied by a proposal to initiate a series of supporting studies.

While many of these "related" studies will provide insights into conditions and changes in Canyonlands, they can not address the unique responses of those systems, nor can they stand to benefit from an enhanced

understanding of conditions and processes in less-altered Colorado River ecosystems, such as exist in Canyonlands.

RECOMMENDED ACTION

Need/Management: The scientific scope of this issue is such that it cannot be addressed by a single research project. Rather, a comprehensive program of investigation is required. The research program will be designed and conducted by the NPS in close cooperation with the National Biological Survey, U.S. Geological Survey, U.S. Fish and Wildlife Service, Bureau of Reclamation and possibly other entities. Furthermore, the program should be designed within the context of related programs occurring elsewhere on the river system. Probably the lead responsibility for establishing a cooperative program of river research at Canyonlands is the Rocky Mountain Region, working closely with the SEUG Superintendent and RM, the Colorado Plateau Research Center at Northern Arizona University and the Washington Office (WASO) Water Resources Division. It may make sense to establish the program within the context of either the Colorado River Annual Operating Planning Program, or as part of the long-term river research authorized by the 1992 Grand Canyon Protection Act.

Research: A comprehensive research program should include research on flow-sediment transport-riparian vegetation interactions. This would involve investigation into the processes associated with the establishment of riparian habitats, and nearshore aquatic habitats such as backwaters and eddies, and the implications of altered flow regimes on riparian and aquatic habitat conditions. Studies might include investigations into the hydraulics and sediment transport of eddies; sandbar deposition and erosion; backwater establishment and fate; main-channel substrate processes and conditions; and water temperature dynamics.

Biological studies should also be initiated, including investigation into the status of native fishes, and their dependent aquatic systems. Also, the function and biological importance of periodically-inundated riparian floodplain habitats to aquatic ecosystems is a critical information need.

Monitoring: Big river monitoring in Canyonlands should be similar in content, though possibly less-ambitious in scope, to the monitoring program being designed for the Grand Canyon by the GCES Senior Scientist in consultation with the National Research Council. That program includes monitoring of discharge, sediment transport and selected sediment features (sandbars, substrate). It also includes monitoring of water quality; the aquatic food base and fishes; riparian vegetation and riparian fauna; and recreation impacts. Except for the monitoring of discharge and sediment transport, most monitoring can occur fairly infrequently on an annual, or even less frequent, basis. Some monitoring may have to be "event" or "occurrence" based.

Inventory: An aerial photograph/ GIS data base should be established to characterize the status of aerially-arrayed resources such as riparian vegetation, backwaters and sediment deposits. Some inventory work related to aquatic benthic flora and fauna, fishes, water quality, riparian vegetation and riparian fauna is needed.

FUNDING

Research: $200,000 per year for five+ years.
Monitoring: $200,000 per year.

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RIVER FLOWS, SEDIMENT TRANSPORT AND RIPARIAN VEGETATION:

DEVELOPMENT OF A LONG-TERM MONITORING PLAN OF RIVERINE AQUATIC RESOURCES IN CANYONLANDS NATIONAL PARK, UTAH
Priority II.1

STATEMENT OF PROBLEM

Approximately 100 miles of the Colorado and Green Rivers flow through Canyonlands National Park (Park) in southeastern Utah. All four species of Colorado River endangered fishes have been recently reported from this region of the upper basin (Valdez 1990, Valdez and Williams 1993), including Colorado squawfish Ptychocheilus lucius, humpback chub Gila cypha, razorback sucker Xyrauchen texanus and bonytail chub Gila elegans. The lower 40-mile section of the Green River in the Park is one of the two most important nursery areas for Colorado squawfish in the basin, while the river in Cataract Canyon supports one of only six remaining populations of humpback chub in existence. Cataract Canyon also supports the few remaining bonytail chub in existence in the upper basin (Valdez and Moretti 1994), and razorback suckers are rare in the park.

Although the distribution and relative abundance of the endangered fishes are documented in Canyonlands National Park (Valdez and Moretti 1994), little is known of resource use and availability. Even less is known about the sensitivity of water quality and macroinvertebrates to a catastrophic event, such as an oil spill or breached waste disposal pond. Detrimental effects on these riverine resources could be devastating to native fish populations, and possibly to species viability. An oil spill from a ruptured oil line was reported in the Yampa River through Dinosaur National Monument in June 1989 (Personal communication with H.M. Tyus, USFWS), with little or no scientific documentation or damage assessment. Fish kills were reported in Westwater Canyon in July 1988 (Personal Communication with B.D. Burdick, USFWS), and in Desolation Canyon in August 1992 (Personal Communication with L. Lentsch, UDWR), also with no scientific documentation of cause or effect.

This proposal details the development of a Long-Term Monitoring Plan for water quality, macroinvertebrates and fishes in the Colorado and Green rivers in and adjacent to Canyonlands National Park. It also describes the development of a Risk Assessment and Rapid Response Plan. These plans can serve several resource management agencies in addition to the National Park Service, including Bureau of Land Management and Utah Division of Wildlife Resources.

RECOMMENDED ACTION

The purpose for this proposal to is develop and initiate a Long-Term Monitoring Plan for Canyonlands National Park. This plan will establish a baseline of existing water quality and macroinvertebrate and fish populations in the Colorado and Green rivers in, and adjacent to, the Park in order to assess the level of environmental damage from a catastrophic event, such as an upstream oil spill or breached waste retention pond. The objectives of the plan are to:

1. Characterize seasonal water quality from U.S. Geological Survey gauges and measurements at sample sites,

2. Determine aquatic macroinvertebrate species composition and relative densities at six sites for distinct habitats used by various fish species,

3. Determine fish species composition, distribution and relative abundance at six sites for distinct riverine habitats,

4. Identify candidate sources of catastrophic perturbations that could affect water quality, macroinvertebrates, or fishes in the park, and

5. Conduct a literature search of sensitivity by fish and macroinvertebrate species in the Park to potential toxicants and pollutants, and develop a Risk Assessment and Rapid Response Plan.

STUDY AREA

The study area will be the Colorado and Green Rivers, in and adjacent to Canyonlands National Park. Two options are presented for cost considerations. Option 1 would include two sample sites, each on the Colorado and Green Rivers above their confluence, and two sites below their confluence above Lake Powell, for a total of six sites. The two sites on the Colorado River above the confluence will be at Shafer Canyon at river mile 34.8 (RM 34.8) and Salt Creek (RM 3.5). The two sites on the Green River will be at Ruby Ranch (RM 97.0) and Millard Canyon (RM 33.5). The two sites below the confluence will be at Rapid 11 (RM 207.2) in Cataract Canyon, and at Imperial Canyon (RM 200.0). Option 2 would sample only the four sites above the confluence.

PROPOSED METHODS

The study would begin in fall 1994. Each sample site contains a complement of shoreline and habitat types that will be sampled for macroinvertebrates and fishes to characterize species composition and relative abundance by habitat type. The habitat types will be (1) cobble riffles, (2) shifting sand runs, (3) backwaters, (4) vegetated cutbanks and (5) silt-sand beaches.

Each site will be sampled once in fall. The frequency of sampling may be reduced or sample sites modified in developing the final Plan.

Objective 1: Water Quality

Water quality will be characterized using the U.S. Geological Survey gauges at Cisco, Utah (Colorado River) and at Green River, Utah (Green River). Additionally, Hydrolab datasondes will be deployed on each river above the confluence to monitor water quality between trips, and Hydrolab Surveyor III's will be used to collect data during the field trips. Water quality parameters to be measured include: temperature, dissolved oxygen, pH, conductivity.

Objective 2: Macroinvertebrates

Macroinvertebrates and fishes will be sampled within each of the five distinct habitat types identified above. Macroinvertebrates will be sampled with a Hess sampler in cobble riffles, and with Ekman or ponar dredges in runs, backwaters and beaches. Vegetated cutbanks will be sampled by selecting a minimum number of branches. A minimum of three samples will be taken in cobble riffles, backwaters and beaches. Additional samples will be taken in shifting-sand runs, since this habitat is expected to have the lowest macroinvertebrates.

All samples will be washed through a 560 micron mesh, and preserved in 75% ethyl alcohol in individual labeled bottles. Samples will be sorted in the field, when possible, or returned to the laboratory for sorting. Macroinvertebrates will be identified to family, genus or species, according to functional importance (i.e., shredders, grazers, etc.). Densities of macroinvertebrates by taxon will be presented as numbers per square meter or numbers per 100 centimeters of branch. The number of samples expected are listed in Table 1.

Table 1. Suggested macroinvertebrate sample numbers.

SITE	COB/RIF	SH/SAND	BACKW	VEG/CUT	SILT/SAND
Ruby Ranch	3	10	3	10	3
Shafer	3	10	3	10	3
Millard	3	10	3	10	3
Salt Creek	3	10	3	10	3
Rapid 11	3	10	3	10	3
Imperial	3	10	3	10	3
TOTALS:	18	60	18	60	18

Samples collected from shifting sand runs (SH/SAND) and vegetated cutbanks (VEG/CUT) are not expected to contain many macroinvertebrates, and can be processed quickly. Large numbers of samples are collected from these habitats to insure complete coverage. Greater numbers of macroinvertebrates are expected from samples collected from cobble riffles (COB/RIF), backwaters (BACKW) and silt-sand beaches (SILT/SAND). Time for sorting and identification is allocated for anticipated number of organisms in samples.

Objective 3: Fishes

Fish will be sampled in the same habitats as macroinvertebrates. Electrofishing and gill and trammel nets will be used in cobble riffles, runs and vegetated cutbanks. Seines will be used in backwaters and shallow beaches. Each sample effort will be restricted to the target habitat, and treated as a repetition, with fish numbers tabulated by species and age category (young-of-year, juvenile, adult). Fish will be individually measured and weighed, and subsampled where large numbers of a nonnative species are captured. Endangered fishes will be PIT-tagged, consistent with the Upper Colorado River Basin Recovery Implementation Program.

All fish will be released unharmed, and incidental mortalities catalogued, reported to the appropriate resource agencies, and placed in repositories. Densities of fish by species and age category will be presented as catch-per-unit-effort (CPUE)--number of fish per ten hours of electrofishing, number of fish per 100 meters of net per ten hours, and number of fish per 100 square meters of area seined.

Objective 4: Candidate Sources

A surveillance will be conducted of areas upstream, and adjacent to, Canyonlands National Park to identify potential sources of pollutants to the river corridor. Pipeline crossings will be identified, as well as waste disposal ponds, highway and railroad crossings, and industrial sites. Materials stored or shipped in these areas will be identified in order to provide a risk assessment for aquatic resources in the Park.

Objective 5: Risk Assessment and Rapid Response Plan

A literature search will be conducted to identify sensitivity levels for important fish and macroinvertebrate species found in the park. This risk assessment will identify those resources most susceptible to particular toxicants or perturbations. This search will provide the background for a rapid response plan, which will detail reaction and activities needed to document a perturbation in the park. This plan will include a step by step description of response times, sample sites, notes, photographs, sample collections and contacts for additional analyses.

SAMPLE SCHEDULE

Option 1 (2 Crews, 6 Sites)

Sampling under Option 1 will require two crews, primarily because of distance and location of sample sites, and the safety precaution of descending whitewater rapids in Cataract Canyon. Each crew will consist of two biologists--a senior biologist and a biologist. Each crew will use a 16-foot Achilles research boat equipped with an electrofishing unit. One crew will descend and sample the two sites on the Green River, while the second crew descends and samples the two sites on the Colorado River. The crews will meet at the Confluence, and jointly sample Cataract Canyon.

Option 2 (1 Crew, 4 Sites)

Sampling under Option 2 will require only one crew, since all sampling is above the confluence, and does not include the whitewater rapids in Cataract Canyon. The crew will consist of two biologists--a senior biologist and a biologist. The crew will use a 16-foot Achilles research boat equipped with an electrofishing unit. The crew will descend and sample the two sites on the Colorado

River, and ascend the sample the lower site on the Green River.

WORK PRODUCTS

A Long-Term Monitoring Plan will be developed in the first year of the investigation, following two sample trips--one in spring and one in fall. Trip Reports will be prepared following each trip to summarize activities and findings. A Risk Assessment and Rapid Response Plan will also be developed in the first year, that identifies fish and macroinvertebrate species sensitivity and details recommended actions for resource agencies faced with a catastrophic event on one of the major rivers.

Average densities of macroinvertebrates and fishes, as well as typical water quality parameters will be presented in the Long-Term Monitoring Plan to begin to establish a baseline for aquatic resources in Canyonlands National Park.

FUNDING

The estimated cost for option 1 is $15,570.50, while the estimated cost for option 2 is $10,221.20.

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VISITOR IMPACTS TO ECOSYSTEMS:

SOIL SURFACE DISTURBANCES
Priority II.1

STATEMENT OF PROBLEM

Thirty percent of the United States consists of semi-arid or arid landscapes, with much of this land under Federal stewardship. Effective management of this vast resource means maintaining the sustainability, productivity and non-invasibility of the ecosystems found on these lands. Since most current land use practices involve extensive impacts to soil surfaces, it is critical that we understand the short and long-term effects of such impacts on nutrient cycles and soil food webs in these ecosystems.

Many resources in arid lands are susceptible to soil surface disturbances that are associated with human use. Soils in arid regions are often highly erodible, and soil formation is extremely slow, taking 5,000 to 10,000 years or more (Dregne 1983). Compaction of soils results in less water infiltration, increased runoff, less locally available water (Webb 1983, Wilshire 1983) and weakened aggregate stability of the soils (Anantani and Marathe 1974, Dregne 1983). Cyanobacterial-lichen soil crusts are severely impacted by trampling (Brotherson, et al. 1983). These crusts are important for soil stability, reduction of water runoff and reduced sediment production from both wind and water (Harper and Marble 1988, Shields and Durrell 1964, Belnap and Gardner 1993, Fuller et al. 1960, Harper and St. Clair 1985, Gillette and Adams 1983, Hinckley et al. 1983). They also facilitate seedling establishment and survival, and contribute both carbon and nitrogen to associated ecosystems (Belnap 1993a, 1993b, Belnap and Harper 1993, Beymer and Klopatek 1991, Lathrop and Rowlands 1983, Skujins and Klubek 1978, St. Clair et al. 1984, West and Skujins 1977). Nitrogen fixed by these crusts has been demonstrated to be utilized by nearby vascular plants (Mayland and McIntosh 1966, Mayland et al. 1966).

Normal nutrient cycles in these semi-arid regions can also be disrupted by trampling. Cyanobacterial-lichen soil crusts have been shown to be the dominant source of nitrogen, the often-limiting nutrient in desert ecosystems (Evans and Ehlringer 1993; Evans and Belnap, unpublished data), and trampling has been shown to negatively affect fixation activity (Belnap et al. 1993). In addition, trampling reduces soil pore space, thereby placing populations of major decomposers at risk. Reductions of these bacterial, fungal and nematode populations would further reduce the availability of nutrients in trampled systems. Surface and below-ground food web structure is critical in maintaining nutrient cycles, plant growth and decomposition cycles in ecosystems. Litter and organic matter decomposition rates, as well as the fixation, retention and release of N, P, S and micronutrients, can be affected by manipulation of the surface and below-ground food-webs (Ingham et al. 1989). Disruptions of soil food webs can reverberate throughout the ecosystem, affecting macro-floral and faunal components (Hendrix et al. 1990, Coleman et al. 1992), and are therefore of great concern.

RECOMMENDED ACTION

This project will establish if, and how, short-term trampling affects soil microbial community structure, examining the linkage between trampling and the disruption of microbial communities, the disruption of nutrient cycles, and resultant effects on vascular plant nutrient levels. It will give us information on what types and levels of use are sustainable on rangeland resources, aiding in the establishment of management goals. In addition, understanding the structure and role of surface and below-ground biota in healthy ecosystems will provide goals for revegetation and rehabilitation of impacted areas.

The objectives of this research are to establish whether trampling of soil surfaces in semi-arid rangelands:

1. Decreases biologically fixed nitrogen input from soil cyanobacteria and lichens, the dominant sources of nitrogen for these systems;

2. Decreases key decomposer populations in the soils, specifically bacteria and fungi, that break down bound nutrients, making them available to vascular plants;

3. Decreases macro- and micro-nutrients in plant tissue, making these plants less nutritious for livestock and wildlife.

FUNDING

Cost: $25,000/year for three years per soil type

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VISITOR IMPACTS TO ECOSYSTEMS:

PLANT COMMUNITY DYNAMICS IN GRASS-SHRUB STEPPE: INFLUENCE OF SEED MANIPULATION BY SMALL RODENTS ON GERMINATION AND ESTABLISHMENT OF GRASSES AND SHRUBS
Priority: II.1

STATEMENT OF PROBLEM

Current Conditions: Brown and Heske (1990) demonstrated that arid land plant community dynamics can be significantly affected by the presence of Dipodomys species, and they concluded that the genus could be characterized as a keystone genus for arid grass-shrub ecosystems in North America. Extensive grass-shrub ecosystems occur in southeast Utah. The presence of D. ordi, Perognathus species and Peromyscus species make these systems similar to the system studied by Brown and his colleagues. Research into interactions between rodents and plants is needed to identify species important to the maintenance of natural communities and ecosystems in SEUG parks, and to determine whether efforts in restoration of disturbed systems must consider interactions between small rodents and the plant community to be restored.

McAdoo et al. (1983) showed that the ecology of Stipa hymenoides is significantly affected by rodent interactions with seeds and seedlings. Heteromyids, especially Dipodomys species may consume up to 35% of the filled seed produced "in a favorable moisture year" (McAdoo et al. 1983). They do not process empty seeds, and discriminate heavily between seed morphs, preferentially gathering "big black" seeds (90% of seeds in pouches, but only 28% of production in 1978, and 41% of soil seed reserves). The big black seeds have low germination rates without enhancement treatments, but are highly germinable if the lemma and palea are removed. Only 34% of seeds harvested by McAdoo et al., and 38% of seeds from the soil but 94% of seeds from Dipodomys cheek pouches germinated following this treatment. Kangaroo rats removed the lemmas and paleas of about 50% of the seeds they cached. Kangaroo rats are apparently very efficient at relocating caches and eat the emerging seedlings, as well as ungerminated seeds (McAdoo et al. 1983). Seed caches contained large numbers of seeds, averaging 250 seeds/cache, but only 0.4-7% (1-17) of these seeds were found as seedlings in April when surveys were made for caches. Seeds with lemmas and paleas removed may have already germinated and been eaten earlier in the spring, since most caches had been partially excavated (McAdoo et al. 1983), and seedlings were primarily from intact seeds (i.e., lemmas and paleas present). Stipa hymenoides seeds germinate best at a depth of about 5-15 centimeters (Kinsinger 1963, J. A. Young personal communication). Seed caches were buried at an average depth of 5.5 centimeters.

Kangaroo rats influence Stipa hymenoides reproduction in both positive and negative ways. They consume a significant proportion of yearly viable seed production, even in years favorable to a large seed crop. More seeds are collected and processed than are consumed in a foraging bout, and the manipulations these seeds experience enhance germinability. Dipodomys relocates the caches, and eats seeds and emerging seedlings, reducing the number of potential recruits into the S. hymenoides population. McAdoo et al. (1983) conclude that rodent manipulations of seeds are perhaps necessary for successful establishment of S. hymenoides in the Great Basin.

Heteromyid rodents, especially Dipodomys species, exert a strong influence on structure and functioning of desert grassland and shrub ecosystems (Brown 1987, Brown and Heske 1990a, 1990b; Valone and Brown 1993, Brown and Zeng 1989, Munger and Brown 1981, Brown and Munger 1985, Mun and Whitford 1990, Hawkins and Nicoletto 1992, Chew and Whitford 1992). Work has not been done on the Colorado Plateau on the role of rodents in ecosystem functioning. The systems studied are similar enough to the Colorado Plateau that some of the same processes may be operating, but species composition is different enough that direct extrapolation from one system to another is not

warranted. Studies are needed to identify species and/or processes that structure communities and maintain healthy ecosystems on the Colorado Plateau.

Dipodomys ordi is the only species of kangaroo rat found in southeast Utah, and in most ecosystems it is not the dominant granivore based on abundance or biomass (SEUG unpublished data). A number of questions concerning the importance of kangaroo rats and other rodents in Colorado Plateau ecosystems need to be addressed: Do granivores influence arid grass-shrub ecosystems on the Colorado Plateau like they do in the Chihuahuan desert? If so, what rodents have the greatest impact on production, dispersal, mortality and/or germinability of seeds? How do the different rodent genera affect seeds? Are there differences in how each species handles seeds that affect survivability and/or germinability of the seeds? Are these impacts great enough to have a bearing on plant population and/or community ecology? Does any one species (or genus) exert an extraordinary influence on seed populations? Do rodents play a significant role in structuring plant and/or animal communities and/or proper functioning of ecosystems? Are rodents important only in those systems dominated by large-seeded plant species such as Pinus edulis, Juniperus osteosperma, Coleogyne ramosissima or Stipa systems?

Past Actions: There has been very little work on the Colorado Plateau investigating the relations between small granivores and their food plants (e.g., Zou et al. 1989). However, studies in community ecology of rodents and their influence on vegetation in other deserts indicates some rodents can exert strong pressures on vegetation, and other animals, altering structure of the community (Brown and Heske 1990a, 1990b; Mun and Whitford 1990, Hawkins and Nicoletto 1992, Chew and Whitford 1992). Work has been done at the autoecological scale with some species that are important in SEUG grass-shrub steppe ecosystems (e.g., McAdoo et al. 1983)

RECOMMENDED ACTION

Management and logistics: A long term research project (at least ten years: Brown went 13 years before he saw large differences between treatments) is needed to determine how the rodent community affects plant community structure in park ecosystems. Data could be collected by seasonal park personnel, or graduate students or technicians if the study is contracted out.

Research: Research on interactions between granivorous rodents and plants should consist of exclosure experiments similar to those used in Brown's work (e.g., Brown 1973, 1987; Brown and Munger 1985, Brown and Zeng 1989). There should be a series of sample plots, some with all rodents removed and excluded, others with only a single genus excluded (e.g., Dipodomys, Perognathus, etc.), some with only a single genus allowed into the plots, and others fenced but accessible to all rodents.

Field and greenhouse germination experiments should be conducted using seeds of the major grass and shrub species present in southeast Utah. Seeds should be placed in cages with each mouse genus, collected following a day of handling, and planted in the field and greenhouse. Other seeds could be placed with each genus of mouse in a cage buried in the soil outside, and allow the seeds to germinate directly from their caches. Cache locations should be mapped daily to be able to follow the fate of each one. Some could be excavated after a couple years to see if seeds are still viable, quantify cache characteristics, etc. Some caches should be protected from foraging rodents, to allow all germinated seedlings to escape predation. Unmanipulated seeds should be planted near manipulated seeds under all conditions. After caches have been characterized, cache conditions should be mimicked when planting manipulated and unmanipulated seeds to determine whether manipulation or cache conditions are more important in seed germination and establishment.

Hypotheses to be tested are:

H_{o1}: Seed manipulation by D. ordi does not affect germination rate of seeds of native grasses and/or shrubs.

H_{o2}: Seed manipulation by Peromyscus species does not affect germination rate of seeds of native grasses and/or shrubs.

H_{o3}: Seed manipulation by Perognathus species does not affect germination rate of seeds of native grasses and/or shrubs.

Monitoring: Depending on your perspective, data collection for this problem could be considered under research or as a monitoring task, since it will involve data collection over an extended period. The seed germination plots should be monitored each spring, and the number of seedlings of each species germinating that year should be recorded for each treatment. Survivorship should also be monitored by tracking the cumulative population size of each species. Average germination rates can be calculated for seeds handled by each rodent genus, and for seeds that received no rodent manipulations.

Vegetation analysis should be conducted at least yearly in the exclosures as well. The nested frequency/cover plots SEUG uses for its LTMP would work well. These plots could be located permanently in each exclosure.

Species/Process list: This problem is actually an inventory of the process of seed predation/germination enhancement. We don't know how the rodents in southeast Utah affect establishment of the plants they live with.

FUNDING

Personnel: This project requires a principal investigator (P.I.) who has a strong background in community and/or ecosystem ecology, large scale experimental manipulations, and familiarity with plants and small rodents of the Colorado Plateau. A project like this would require a large crew of unskilled laborers to build the exclosures, and a skilled crew of two each summer to collect data on seed germination, seedling survival and rodent activity inside and outside the exclosures. The P.I. should be a GS-11 permanent position, the two technicians should be GS-6 or GS-7, and the fences could be built using a Job Training Partnership Association (JTPA) or prison crew essentially for free. The greenhouse manipulations should probably be contracted out, and could be done for about $30,000/year, or the whole project could be contracted out for about $150,000/year.

Transportation: Transportation needs may vary depending on where the exclosures are located, a pickup will probably suffice. A General Services Administration (GSA) truck costs about $4,200/year.

Supplies: Fencing is needed to build exclosures, but how much depends on the number of replicates deemed necessary. Brown used only two replicates of each of his treatments, for a total of 24 0.25 hectare plots. He was looking primarily at interactions between rodent species, with 12 different treatments of food and competitor manipulations. His conclusions about the importance of Dipodomys spp. in structuring plant communities were reached by pooling results from four treatments (8 plots) that excluded Dipodomys and comparing those to four treatments (16 plots) that did not exclude kangaroo rats (Brown and Heske 1990a, 1990b). He compared percent cover of various annual and perennial grasses inside fenced plots that did or did not allow access by kangaroo rats using (Analysis of Variance (ANOVA) with 1 and 23 degrees of freedom (df). A minimum of five replicates of each treatment, (df 4 and 24 for five treatments) are recommended, which should be enough to pick out differences between treatments.

The five treatments proposed are: 1) Control: plot delineated but no fence, 2) Control: fenced but no restrictions on access, 3) No rodents: fence without doors or other access for any rodents, 4) No Dipodomys: fenced, but with small

openings that allow P. maniculatus and Perognathus spp. in the exclosures, and 5) Small rodents excluded: P. maniculatus and Perognathus spp. are excluded, but D. ordi can move in and out of the exclosures (if this is possible). Only four of these require fencing. If each exclosure is 50 meter by 50 meter (0.25 hectare), and posts are placed every ten meters, you will need 16 regular fence posts for each plot, and four corner posts. For 20 exclosures (five replicates of four fenced treatments), you will need 320 fence posts and 100 corner posts. The wire should be approximately one-centimeter mesh hardware cloth, about one meter wide, and five replicates of four fenced treatments will require 4000 meters of wire, which will have to be purchased.

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VISITOR IMPACTS TO ECOSYSTEMS:

EFFECTS OF VEGETATION ALTERATION ON INVERTEBRATE COMMUNITIES
Priority II.1

STATEMENT OF PROBLEM

Current Conditions: Community structure of terrestrial invertebrates is greatly influenced by architectural complexity of the plant community (Wing 1984, Hatley and MacMahon 1980, Lawton 1983, Parmenter and MacMahon 1984, Robinson 1981). Greater three-dimensional complexity provides more substrates for phytophagous insects (Lawton 1983) and thus more prey for predators. Artificial reduction of substrate complexity resulted in reduced predator numbers and diversity (Wing 1984, Hatley and MacMahon 1980), while increasing structural complexity resulted in a greater diversity and abundance of invertebrate predators (Wing 1984, Robinson 1981). These manipulations changed species composition of spider communities as well.

The three-dimensional structure of plants is affected by humans directly by breakage and trampling, but also more slowly via changes resulting from trampling, in relative abundances of species, and species composition of the community. Belnap et al. (1993) have shown that trampling soil cryptobiotic crusts reduces the nitrogen-fixing capabilities of the crusts, and since nitrogen fixed by crusts is a major nitrogen source for vascular plants, the nutrient status of plants may be adversely affected by trampling. Vascular plants depend on soil crusts for much of their available nitrogen in cold deserts (Evans and Ehlringer 1993), thus plants in trampled areas may experience nitrogen shortages which could affect their nutritional quality for herbivores. Other stresses associated with trampling (e.g., increased water runoff, decreased water availability) may also affect nutritional status of plants for herbivores (Mattson 1980, Mattson and Haack 1987a,b) resulting in different nutritional status of plants in disturbed and undisturbed areas. In response to these differences herbivores may shift food plants, change feeding locations and/or increase consumption. Herbivore population responses could range from local extinctions to explosions depending on plant responses and the herbivore species involved. All three responses have important implications relative to the maintenance of ecosystem health in the parks of the Southeast Utah Group.

Past Actions: There is a large body of plant-animal literature available on which to base hypotheses for investigating the impacts of changes in plant community characteristics on invertebrate communities. However, there has been little work that addresses these interactions on the Colorado Plateau.

RECOMMENDED ACTION

Management/Logistics: This problem should be addressed as a long term research project, with experimental manipulations simulating heavy, moderate, light and no visitor use/impact on pristine vegetation. A research contract would probably be the best approach.

Research: Documentation is needed on the effects on invertebrate communities of a) trampling/breakage of plant parts, b) changes in species composition/evenness as a result of visitor pressures, and c) changes in the nutritional quality of plants because of changes in nutrient availability caused by reduced activity of cryptobiotic soil crusts. The research proposed here cannot be done until the direct and indirect impacts of visitors on plant communities have been quantified.

Invertebrates will probably respond most quickly to the physical changes in plants in their habitat. Both herbivores and predators will be directly affected by changes in architecture, while changes in nutritional status of the plants will impact different trophic levels at different rates, and changes in plant community composition will take even longer to occur; invertebrate responses will be correspondingly

slow, and thus much more difficult to document.

Experimental changes made in structural complexity of the plant community will necessitate some trampling of soil crusts adjacent to damaged plants. Depending on the sphere of influence of trampling may be able to alter architecture from a distance that will not affect responses to trampling directly. Thus, results could be confounded if data are not collected repeatedly through the study. To separate nutrient status and architectural influences on changes in invertebrates, these two treatments should be run within a single experimental design: Control, crust trampling alone, crust trampling plus breakage. Care must be taken in sampling that plant architecture is not significantly altered by the sampling activity itself.

Hypotheses to be tested:

H_{o1}: Invertebrate community composition (species abundance and evenness) will not change following reduction in structural complexity of plant community.

H_{o2}: Invertebrate community composition (species abundance and evenness) will not change following trampling of crust and the subsequent reduction in plant nitrogen.

H_{o3}: Invertebrate community composition (species abundance and evenness) will not change following shifts in plant community composition (e.g., species replacements, changes in abundance, etc.) resulting from plant mortality and/or replacements related to trampling.

Species/Processes List: The plant and invertebrate communities have to be documented before any manipulations take place. An architectural complexity classification will have to be developed to quantify this aspect of plants, and to ensure comparability between plots and treatments. Plant responses to trampling and breakage must be quantified first to know what manipulations of plants are needed.

FUNDING

Personnel: This project requires someone familiar with the terrestrial invertebrates of the Colorado Plateau, and with connections to experts in the taxonomy of invertebrate families. This project would be best accomplished by contracting. A number of technicians would be needed to sample the invertebrates, delineate plots, etc.

Transportation: A truck will be needed.

Supplies: No special equipment will be needed beyond the normal invertebrate sampling gear. Ensuring that all invertebrates are accurately and adequately sampled will be a challenge.

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VISITOR IMPACTS TO ECOSYSTEMS:

ALTERATION OF VEGETATION BY VISITORS: EFFECTS ON VERTEBRATE COMMUNITIES
Priority II.1

STATEMENT OF PROBLEM

Current Conditions: This project will be very similar to the above invertebrate study, and perhaps could be conducted in the same areas, although the disturbance from two studies could bias results from both of them. There is a large body of literature on the influence of architecture on bird species diversity, and some on mammals and reptiles.

VISITOR IMPACTS TO ECOSYSTEMS:

SOIL FOODWEB CHARACTERIZATION
Priority II.1

STATEMENT OF PROBLEM

Soil is an integral part of any terrestrial ecosystem and is the basis for sustainable systems. There are few areas of the world more important to humankind in general, but less well-studied, than soil. Soils, if healthy and functioning properly, provide a variety of services, such as (1) clean water, (2) clean air, (3) nutrients for plant growth, (4) edible fungi, (5) food for small mammals, birds and insects, (6) a reservoir of antibiotic-producing organisms (medically useful antibiotics originally came from soil bacteria or fungi), (7) a reservoir of biocontrol and beneficial organisms, (8) a sink for large quantities of carbon, nitrogen and other nutrients that, if freed, would result in degradation of the human environment, and, of course, (9) aesthetic beauty. These services are often taken for granted, but the biotic component of soil, and therefore its function, is a resource that is rapidly being destroyed.

Once those services are destroyed, can they be restored? We first have to know how those services are provided, (i.e., who provides them and what controls their performance?), in order to put them back the way they were. Otherwise, how can we know when function has been restored? We need to know how to sustain those services in places where these functions have not yet been destroyed. Once soil begins to be degraded, we must be able to recognize the steps through which an ecosystem moves on its way to desertification. Can we take short cuts in the restoration process and return degraded systems to full function within a short period of time?

While there have been a limited number of studies of soil foodweb structure, it is clear that organism numbers and identity directly relates to nutrient cycling processes and soil health (Ingham et al. 1986a,b; Coleman 1992, Hendrix et al. 1990). Our understanding of species richness in different ecosystems for any specific group of soil organisms is limited, and while we have a broad concept of the relationship of ecosystems and function, we know little about the relationship between diversity and function in soil organisms, i.e., soil biodiversity. In fact, our understanding of the regulation of any soil organism population is minimal and needs further investigation.

Soil foodweb organisms can respond more rapidly than plants to environmental change and disturbance (Ingham et al. 1986a,b; Coleman 1992, Hendrix et al. 1990, Paul and Clarke 1989). Activity of soil foodweb decomposers, i.e., bacteria and fungi, often reflect daily or weekly fluctuations in temperature, moisture, grazing and nutrient availability. General bacterial and fungal biomass and activity tend to respond on a seasonal basis to carbon availability, temperature and moisture. Ratios of fungal to bacterial biomass, or percent activity of bacteria and fungi assess longer temporal scales of resolution with respect to impacts on ecosystems (Ingham and Horton 1987). Protozoa and nematodes are intimately involved in processing nutrients within ecosystems (Coleman 1985) and are indicators of rates of nutrient cycling and ecosystem health (Hendrix et al. 1990, Ingham et al. 1986a,b; Ingham and Horton 1987). Bongers (1991) has suggested that the ratio of consumer to predator nematodes present in the soil is a direct measure of the health of that soil.

In recent work on soil foodweb structure and function in Canyonlands National Park (Belnap and Ingham, in preparation), the soil foodweb structure in recovering areas has been elucidated. Cyanobacteria, algae, eubacteria and fungal components of the system are clearly of great importance in maintaining the services which the soil system provides in these ecosystems, including maintaining soil integrity and preventing massive soil erosion, fixing nitrogen for continued plant productivity and maintenance of the native grassland and juniper vegetation, prevention of loss of nutrients from the soil.

Intact cyanobacteria/ lichen crust communities are critical in maintaining the services offered by soil, and thus it is critical to understand those processes which enter into development, maintenance and restoration of these crust communities.

Soil organisms which prey on the bacterial, algal and lichen components of the crust may be important in maintaining activity of the communities. Alternatively, when the system becomes unbalanced, these predators may overgraze their prey populations, or subject the prey to too little predation, such that nutrient cycling is limited and plant productivity suffers.

Interactions of soil organisms with plant roots has been shown time and again, to be critically important in plant germination, growth, competition and succession. For example, the differential colonization of plant roots by mycorrhizal, saprophytic or pathogenic fungi has been shown to influence the course of plant succession, from one dominated by alien invaders to one dominated by native plant species.

The carbon input to the soil from fine/coarse/structural roots and from litter material are significant portions of the carbon cycle in soil. This carbon is present in a variety of forms: simple sugars, proteins, carbohydrates, cellulose, lignins, auxins and other complex, structural recalcitrant compounds and become part of the soil through a variety of pathways mediated by soil bacteria and fungi. Exudation of carbon through living root tissue into the soil, supports a massive increase in bacterial numbers around roots, and thereby supports the bacterial-based foodweb in soil. These exudates, in the right amounts and types, select for mycorrhizal colonization of the root itself, benefitting plant nutrition and competitive ability. Sloughing of root cells supports the growth of saprophytic fungi as well as certain types of bacteria, thus supporting the fungal-based foodweb, as well as excluding certain types of root-feeding pests.

Bacterial and fungal predators interact with plant beneficial, neutral and detrimental bacteria and fungi. Predators of nematodes interact with the beneficial nematodes, i.e., fungal and bacterial feeding nematodes, as well as plant-parasitic nematodes. Many of these interactions control plant growth and successional processes, but our understanding of their importance, timing and manipulation is lacking in semi-arid and desert ecosystems.

Thus, to improve our ability to appropriately manipulate the soil foodweb, to maintain native ecosystems and to achieve restoration successes, we must understand soil foodweb structure and function in these ecosystems.

RECOMMENDED ACTION

This work will be performed in conjunction with the GIS studies of aboveground plant and animal communities. With this in mind, number and placement of sample sites will be determined by all cooperators working together at the beginning of the study. Sampling sites will be selected from the set of all habitats within the parks. A set of five to ten habitats will be chosen, based on determination of the most typical habitats, i.e., habitats with greatest area within the parks, or having critical importance to the Park's mission.

Three to five sites will be chosen from each of the five to ten habitat types (maximum of 50 sites) and these sites sampled for all soil foodweb organisms. Exact sampling layout in each site will depend on the variance determined during an initial survey of each site to be performed in the spring of 1994.

Following this initial intensive work, seasonal sampling will begin. Samples will likely be taken once in late October, after fall rains/snows have begun, and again in the late spring after plants are rapidly growing, but before the soil dries in the heat of the summer. Currently, based on work by Belnap and Ingham, maximum nitrogen fixation is thought to occur

during the winter months when crust communities are not stressed for moisture or temperature. Crust communities are dark in color, and thus likely warm sufficiently in the winter months to allow the rate of biological processes to be quite high. If deemed reasonable, additional sample dates in late summer (maximum dormancy) and in late winter/early spring could be taken as well to allow determination of the entire seasonal dynamics.

In general, on each sample date, five sets of ten random 2.5 centimeter diameter by 10 centimeter depth cores should be taken in each site, and the core split into 0-5 centimeter and 5-10 centimeter depths. An additional sample of the top 1-2 centimeters could be taken on certain sample dates to focus in on the cryptobiotic crust community separate from the lower depth communities.

The ten cores will be bulked and well-mixed. Soil for determination of each foodweb organisms group will be removed from these bulked samples, such that five representative values for each organisms group will be obtained for each site.
Each soil sample will be assessed for: (1) active bacterial numbers, (2) active hyphal length and biomass and (3) total fungal length and biomass by the FDA method of Ingham and Klein (1984); (4) total bacterial numbers by FITC staining (Babiuk and Paul 1970); (5) protozoa numbers by MPN technique (Darbyshire et al. 1974), (6) nematodes numbers by Baerman extraction and microscopic observation (Anderson and Coleman 1977) and (7) microarthropod numbers and community structure, where appropriate (Standard Operating Procedures available from the USEPA for each of these organism groups: USEPA Corvallis Environmental Research Laboratory, 200 SE 35th, Corvallis, OR 97333).

Since roots are critical inputs to the soil and are important to plant productivity, root biomass (total dry weight) and mycorrhizal colonization of roots will be performed by clearing and staining, roots, followed by examination of roots to determine percent colonization and, where possible, mycorrhizal genus/species.

ANALYSIS

Soil foodweb structure will be determined, which allows a direct estimation of nutrient cycling performed by soil organisms, and an assessment of which soil services are actually provided by the soil system. In sites impacted by disturbance, analysis of the soil foodweb will allow determination of which soil organism groups have been negatively impacted, perhaps entirely removed by the disturbance, and thus, which soil foodweb organisms groups, or species, need to be returned to the soil in order to return soil function.

Based on this work, the important components of the foodweb, i.e., soil biodiversity, can be determined and monitored for each different soil system examined.

FUNDING

$30,000 per habitat type

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VISITOR IMPACTS TO ECOSYSTEMS:

WATER QUALITY
Priority II.1

STATEMENT OF THE PROBLEM

The primary bodies of water in SEUG are the Green and Colorado Rivers. Three permanent, and several temporary streams and washes are present in the parks, which are fed by various springs and seeps throughout the parks. As water is a limiting element in the desert, maintaining healthy water systems is crucial to all of the SEUG ecosystems. The primary threats to water quality of the rivers are upstream development and oil or chemical spills. For this reason, SEUG needs to develop a baseline database of current conditions of aquatic life in the rivers, so they may be prepared to develop a Natural Resource Damage Assessment (NRDA) if a disaster were to occur. This issue is addressed in the proposal on benthic macroinvertebrates in Appendix IV. The primary question to address regarding river water quality is:

1) What is the current condition of aquatic macroinvertebrates in the Green and Colorado Rivers? If a chemical spill or oil-related impact arises later, how will the park be able to document the damages which have occurred? Baseline and condition data are necessary to develop an NRDA. In addition to spills, oil seeps from nearby oil and gas development and overgrazing are potential problems.

Water quality of springs, streams, seeps, plunge pools and potholes in SEUG also face other threats. Trespass grazing affects the water quality of a few springs in Arches and in western Canyonlands. These impacts are limited in area and would be resolved by the construction of a boundary fence. Oil and gas development could present problems to the park if aquifers are connected or leaching occurs. With the exception of Natural Bridges, most current development is at least ten miles from the borders, and does not currently present threats to water quality. Internal development is another threat. A spring in the Needles may be impacted by the leach field for the new residence area.

Another issue that should be addressed are the radioactive mine spoils that have been left in the vicinity of water sources in the park. Many potential sources in the general area and in watersheds exist, and there has already been some contamination in some springs. If the superfund site above Moab contaminates the river, damage potential is high. Given all of these factors, some monitoring of radioactivity might be appropriate. At a minimum, water monitoring survey crews should carry an implement to check for hot spots.

The primary threat to non-river water sources in SEUG is visitation. Visitors frequently use water sources for washing or bathing. The effects that these activities may have on the water quality are unknown.

The second question regarding SEUG water quality is:

2) What are the impacts of visitor use on pool and spring aquatic habitats? Concerns include trampling, sedimentation, sunscreens, repellents, body oils and salts, and general disturbance. These springs and pools are quite small and are heavily used for bathing when it gets hot, so the impacts are quite concentrated on these small bodies of water. Undetected damages may have already been done to snails or other potentially rare or endangered organisms.

RECOMMENDED ACTION

Objective 1: Develop baseline data on river water quality.

Objective 2: Determine the impacts of visitor use on pool habitats.

1. Classify the various pool types by substrate, vegetation cover, water quality differences and human use intensity.

2. Conduct a pilot training session so that data collectors become

familiar with macroinvertebrate taxa in pools.

3. Locate several upper drainage/least impacted pools to compare with several heavily affected pools. Try to find the three least impacted pools and the three most impacted for direct comparisons.

4. Gather information of interest in each pool:

A. Relative or absolute human use intensity
B. Pool geometry--make a bathymetric map of the pool and establish a benchmark for quickly determining pool volume.
C. Water Quality Data:
- Flow
- Temperature profile
- Air temperature
- Alkalinity
- Sulfate
- Secchi Disk reading (measure three times each pool)
- Hydrolab Information: pH, DO, conductivity

D. Macroinvertebrate and plankton data

An adaption of EPA's Rapid Biological Assessment Protocols or the Utah State Rapid Bioassessment protocol may be used. BLM, USFS and the USGS National Water Quality Program (NAWQA) have all developed biomonitoring protocols. It would be valuable to compare the methods and create a method that would work well for rapid biological assessment in the SEUG spring/pool habitats.

FUNDING

$30,000 per year

GEOGRAPHIC INFORMATION SYSTEM (GIS): DEVELOPMENT AND APPLICATION
Priority II.4

STATEMENT OF PROBLEM

SEUG has successfully pursued acquisition of GIS hardware. The system is currently on line and databases are being acquired and developed. Applications are being developed as needs arrive. In addition to the three parks in SEUG, SEUG acts as the GIS node for Colorado National Monument.

In 1992 SEUG received GIS hardware and Grass Software to begin running a Geographic Information System. In Fiscal Year 1994 (FY94), funding was approved for hiring a full-time GS-11 GIS Specialist. SEUG began developing a database in 1990 but has little available to date. The geologic theme is ready for input. Hydrography should be available during 1994. Soils information is in various stages of development. SEUG has made contact with other public agencies in an effort to acquire available databases. In addition SEUG will be the GIS node for Colorado National Monument. Set up of the hardware and initial set up of the software will take some time but database development will be very time consuming. The Grand Junction Area Office, BLM has most information digitized for the window that will include Colorado National Monument. In 1993 the park produced the Canyonlands National Park Backcountry Management Plan map. A map displaying Russian knapweed infestation and control efforts was completed in October 1993.

RECOMMENDED ACTION

Management: GIS allows for the integration and manipulation of georeferenced information. It replaces hardcopy maps with digitized information. These digitized maps can be overlayed, integrated and changed in scale to accommodate each specific need. While start up costs are large the result is a net savings in personnel time and more accurate mapping.

The hiring process has begun for a full-time GS-11 GIS Specialist. This program requires up to half of the Natural Resource Specialist's time in the absence of a GIS Specialist. In the near future, it will be desirable to hire a GIS Technician Assistant to perform the time consuming work of digitizing. Initial efforts will acquire available databases and incorporate them into the system. Current Backcountry Management Committee mapping needs have placed immediate demands on the system. The park needs to purchase Global Positioning System (GPS) equipment. A small hand-held unit was ordered in late 1993 for field testing. The park needs to acquire a Trimble Pathfinder as a minimum for GPS support at a cost of $8,000.

One of the most critical themes to be developed is a vegetation map. This should include:

1. Providing a GIS base map of the park's vegetative/cover.

2. Assigning all recognized vegetative types to appropriate categories in the Brown, Lowe and Pase vegetational classification scheme.

3. Quantitatively describing all vegetational types recognized.

4. Developing indices of uniqueness and post settlement disturbance for each vegetative type recognized.

FUNDING

Cost Estimate: The Rocky Mountain Regional Office (RMRO) has acquired the hardware for the system. SEUG costs will be in personnel time for the GIS Specialist. It is anticipated that this will be $32,000. in 1994, and $51,400. in subsequent years. The Programmer Analyst will be used for one day per week at a cost of $2,300 per year. $15,000 is needed to support database acquisition and development. $8,000 is needed to acquire a Trimble Pathfinder GPS. The park is currently seeking funds to acquire an optical scanner to increase the available memory storage on the GIS mass storage device. This will allow the park to

use digitized orthophotoquads and state of the art AVIRIS (Advanced Visible Infrared Imaging) photography that has been taken of various sections of the park.

Vegetation maps will cost $100,000.

Total Estimated Project Cost: FY94 cost is estimated to be $34,300 (FY95 = $53,700) for personnel costs. $15,000 is needed to begin database development. A further $18,000 will be needed to acquire GPS and expand the memory capabilities of the Mass Storage device with an optical scanner. $100,000 is needed for vegetation maps.

Estimated Time To Complete Project: Two years is needed to establish an effective GIS. After that time the system should be fully functional. A vegetation map will take two years.

ENDANGERED SPECIES: FISHES
Priority II.5

STATEMENT OF PROBLEM

There are four species of endangered fish in the Upper Colorado River Basin and much of their habitat is within Canyonlands National Park. Colorado squawfish are the most common. A population of humpback chubs persists in Cataract Canyon and razorback suckers have been captured in the park from time to time. In June 1993, over 100 larval razorback suckers were recovered from the upper portion of the Green River in the park indicating that portions of the park may be important nursery habitat for this species. The National Park Service is a major land owner along the Colorado River and as such has much of the available habitat for these fish. It is essential that the NPS be involved in all phases of the recovery of these fish. These endangered fish represent a major recovery effort by state and Federal agencies and are a potential source of political conflict.

Prior to 1992 NPS has been involved only as an observer. NRPP monies are now available from region and a Fisheries Research Coordinator has been hired. The Natural Resource Specialist currently spends two weeks per year in the field in support of this program, one week per year in attendance at meetings and one week per year in coordination of endangered fish activities. An inadequate amount of time is devoted to this function. Duties may change with the new RMRO direction into this effort. It is envisioned that the Natural Resource Specialist will spend more time in the field in FY94 with cooperating agencies.

RECOMMENDED ACTION

Management, Research, Monitoring: These fish are Federally listed as endangered and must be protected by law. Canyonlands National Park has an important portion of the available habitat for these fish. It is likely that recovery activities will occur in the park in the near future and the NPS must be able to be proactive in participating. At a minimum, Resource Management must become actively involved in supporting the efforts of the Fisheries Research Coordinator for the next three years and must be prepared to continue fisheries efforts once research activities are complete. Activities for which Resource Management will likely be responsible are annual census efforts; maintenance of fisheries management activities such as maintaining floodplain habitats; related exotic plant control activities; and possibly some exotic fish control work. The Natural Resource Specialist will be responsible for coordinating with the Fisheries Research Coordinator to accomplish this effort. Currently the Resource Management Division has limited capabilities on the river and needs a flatwater boat. Since there are engines available in-house, it is anticipated that the park could acquire a johnboat for between $1,000 and $1,800.

FUNDING

Cost Estimate: SEUG Resource management currently expends $1,200 annually in personnel costs and $300 in travel to support this project. In FY92 RMRO began receiving NRPP monies in excess of $700,000 per year. This supports a Fisheries Research Coordinator for the Colorado Plateau. The park will continue to be involved in this project and additional money may be available for project work. The park needs $1,000 to $1,800 to acquire a johnboat.

Total Estimated Project Cost: $1,500 per year at the current level. The Recovery Program is beginning to move into a management phase and additional duties at the park level will likely expand. A one time charge of $1,000 to $1,500 is needed to purchase a johnboat to support field work.

Estimated Time To Complete Project: Ten years.

SENSITIVE SPECIES:

DESERT BIGHORN SHEEP
Priority II.6

STATEMENT OF PROBLEM

There are desert bighorn sheep in Arches NP and all three districts of Canyonlands NP. The health of these herds and the amount of disturbance each is subjected to varies widely. Arches has a small herd which was established by 1985 and 1986 reintroductions from Island in the Sky. This herd is subject to extensive human interactions along Highway 191 and the Colorado River. The herd appears to be healthy and growing. It is contiguous with a small herd in Professor Valley established by a 1991 release. There is also some interaction with the Potash/ Island herd (below) when animals cross Highway 191, but the extent of this interaction is unknown. A determination should be made as to whether a widening of the highway would impact this interaction.

The Island in the Sky herd is contiguous with the Potash herd on public land north of the Park. There is much interaction between animals of both units. These herds appear to be in good health, although blood tests show the animals have titers to many diseases that can compromise herd health (bluetongue, parainfluenza-3). Scabies is also present in the herd, but not at levels of concern. Both the Island and Potash bighorn are subject to high levels of human disturbance from the growing recreation use in this area.

The Needles herd is contiguous with bighorn on surrounding public land. These herds (Needles and North and South San Juan units on public land) have experienced serious disease problems since the mid-eighties, and overall numbers have decreased. There has also been very poor lamb survival. These bighorn are subject to human disturbance in specific areas such as Cataract Canyon and Red Canyon. There is, however, a large area of habitat that is isolated and receives minimal recreation use.

The Maze herd, which was also transplanted from the Island, appears to be healthy, but little is known about these animals. In January, 1993, several of these animals were captured and radio-collared. Blood was drawn for disease workups, but no analysis has been done yet. This District still has fairly light human use. The Arches and Maze herds are both small, and neither are dispersing far into available habitat.

Overall there are two immediate problems that need to be resolved to maintain viable herds in the Parks. First, herd health needs to be evaluated and the causes of disease problems identified. Second, it is important to identify how much and what types of human disturbance these herds can tolerate. The two questions are interrelated since human disturbance can cause physiological stress, and that in turn can reduce an animal's ability to fight off disease. These problems are not unique to SEUG Parks. They also occur on surrounding public lands; similar problems of human disturbance have been identified in California and Arizona, while disease outbreaks have been documented in both desert and Rocky Mountain bighorn sheep in nearly every state in the West.

In order to protect these resources, accurate census information is needed that includes population size, reproductive success and population structure. Continual monitoring is needed to provide information on critical use areas, limiting factors, reactions to visitors, disease, carrying capacity, movements and unoccupied habitats. Populations with surplus animals need to be identified in order to provide individuals for transplants to areas where desert bighorn have been extirpated. A sightability model is currently being developed to provide SEUG with an accurate census method. Some work is being done currently on diseases, population dynamics and genetics on the Island in the Sky herd. This work needs to be expanded to other herds.

A number of bighorn studies have been conducted in southeast Utah. Most of these looked at either herd health

and/or reactions of bighorn to human disturbance. An annotated bibliography is attached; it also identifies other papers that dealt with these topics. Currently SEUG supported activities with desert bighorn sheep are limited to $7,000 for helicopter time committed to the annual census. This work has been discontinued while the NRPP funding by RMRO is in place to develop the sightability model. Twenty-six desert bighorn sheep were collared in the Canyonlands National Park as part of the development of an accurate census technique. The selected census technique involves a sightability model which allows for the accurate counting of sheep based on the number seen from an aircraft. This simplifies the former technique which relied on numerous ground observers and was considered inaccurate.

Irvine (1969) collected limited disease information on 12 rams shot during hunts. Mike King and other graduate students from Utah State conducted lengthy research on bighorn in Red and White Canyons from 1981 to 1988. They also summarized some disease history from the Needles District. They documented the South San Juan disease outbreak from its inception, and their reports have much valuable information on diseases found in herds both on public land and in the National Park.

King also did a comparison study of bighorn reactions to human disturbance in two bands of bighorn, one that is frequently disturbed and one that is fairly isolated from disturbance. Another graduate student, Mark Stanger, looked at interactions between boaters and bighorn in Cataract Canyon. Bill Bates (1983) studied the Island in the Sky herd; he noted that human disturbance caused temporary displacement of bighorn from some areas. Haas, Workman and Bunch (1990) summarized disease history of ten animals transplanted into Arches from the Island. They also conducted human interaction studies, measuring responses to various types of disturbance.

While a number of human interaction studies have been done in this area, all measured only behavioral responses (flight/no flight) rather than physiological responses such as heart rate or body temperature. King's study identified the most serious concerns in his Red Canyon group (where there is a great deal of human use). He felt that interruption of foraging might be a serious problem leading to nutritional deficiencies (especially in the summer for lactating ewes) and that more research should be conducted on the aspect of disturbance.

RECOMMENDED ACTION

Management/Logistics: Since these problems are not unique to SEUG, the NPS Rocky Mountain Regional Office should also be involved in research. They have access to wildlife veterinary expertise that will be essential in such research. The Bureau of Land Management should also participate in this research since herds do not recognize park boundaries; management of livestock and human uses on surrounding public land affects bighorn in the parks and vice versa. Finally, it is essential that Utah Division of Wildlife Resources participate in the work since they manage wildlife on public land. Their big game biologists are experienced in capturing and handling animals, and they have the capability to do aerial tracking. These work items could be done by park staff or under contract, but it would be more cost-effective to have the state agency do it as part of their regular workload.

Following development of the suitability model, SEUG will need to commit for four days of flight time at $12,000 per year to census all four park herds. One GS-5 Wildlife Technician (.5 FTE) is needed for a seasonal position to do field work on desert bighorn sheep to provide information for park management. This position would provide management with crucial information on the status and reproduction of desert bighorn sheep.

Research: Bighorn from different districts and areas on public land should be captured and blood samples taken. Observations during UDWR's annual aerial surveys suggest that

some herds are healthy (Maze, Island, Potash), some have active disease outbreaks (North San Juan), and some that were decimated by disease may now be recovering (South San Juan). Analysis of blood samples can identify both what bighorn have been exposed to (titer levels) and possibly isolate active viruses. Sampling lambs will show whether diseases are now active. If adults exhibit disease titers that lambs do not have, the disease is probably no longer active. If lambs also have these titers, disease is still active. When bighorn are captured, they should be radio-collared, both for the immediate research project and for long-term monitoring. If a radio-collared bighorn dies, it may be possible to find the animal quickly enough for a necropsy.

If human disturbance studies are to be done, it is recommended that some measure of physiological response be used rather than behavioral observations. The latter type of work has been conducted by several researchers in southeast Utah in the last ten years. King (1984) suggested that efforts should be made to determine how much energy is expended when bighorn are harassed and whether the available forage possessed enough nutritive value to make up for energy costs. He also suggested that research should determine the degree to which animals can compensate for energetic costs by behavioral adjustment.

Capturing bighorn with associated blood work and radio-collaring is the first priority; follow-up on these animals is second priority; disturbance research is third priority.

Monitoring: In the first year of research, all radio-collared bighorn should be tracked as frequently as possible. This will give researchers a chance to pick up mortalities soon enough to identify the cause of death. Tracking will also identify what areas bighorn are using seasonally; in the long term this will assist managers in minimizing human disturbance.

Another important aspect of monitoring is that reproductive success can be quantified. One of the most important overall indicators of herd health is lamb/ewe ratio (20-40/100 is considered a stable herd); having collared animals will greatly facilitate population surveys.

In the past UDWR has not had funding to survey all herds, and non-hunted herds are often not counted. For the duration of this research, it will be important to survey all areas in southeast Utah. If UDWR does not have sufficient funding, NPS and BLM should try to jointly fund these surveys.

Process: If we follow King's suggestions for research on energy expenditure, preferred forage species such as blackbrush and galleta may need to be analyzed for nutritional content at different seasons and under different precipitation regimes. It might also be useful to have captive bighorn for measures of energy expenditures.

FUNDING

All figures assume two years work. It is likely that some monitoring would be done in following years, but these costs are not estimated at this time.

Personnel: Capture crew of three people plus veterinarian for one week (if participating agency staff are used, no additional cost). One to two seasonal technicians for two years (estimated at $50,000).

Transportation: Vehicles for technicians at $10-15,000.

Supplies: Radio collars at $12,000; spotting scopes and binoculars at $1,500; receivers and antennae (4) at $2,500; blood analysis at unknown cost; contract for nutritional analysis and captive animal work at $25,000; helicopter time at $35,000; fixed-wing follow-up flights at $30,000.

Cost Estimate: $4,000 have been allocated by SEUG Resource Management for the project with another $2,000 of personnel time and $500 of travel allocated to this project. RMRO is

paying the bulk of the helicopter time and related expenses for this project at a total $23,000.

Total Estimated Project Cost: $29,500

ANNOTATED REFERENCES

DISEASE TOPICS

Haas, C. Shirlene, Workman, Gar W., and Bunch, Thomas D. 1990. Final report; an analysis of composition, distribution, and habitat use of reintroduced desert bighorn sheep in Arches National Park, Utah.

Haas reported on disease workups from blood samples taken when the Arches bighorn were transplanted (all came from Island in the Sky District). Ten samples were analyzed: only two had titers to parainfluenza-3, leptospirosis, and epizootic hemorrhagic diseases; three had titer to bluetongue. None of the ten had titers for infectious bovine rhinotracheitis, brucellosis, or bovine virus diarrhea.

Helprin, William D., Haas, C. Shirlene, Bunch, Thomas D., and Workman, Gar. W. 1990. 1990 final report; the ecology of desert bighorn sheep in southeastern Utah. BLM Contract Number YA-533-CTO-1068.

The researchers attempted to determine the causes of declining reproductive success in the South San Juan bighorn herd. They conducted their study in 1987 and 1988. They found 30 lambs/100 ewes in 1987 and only 9/100 in 1988. Sick bighorn were observed throughout the study, and remains of a number of young bighorn were found. One carcass was fresh enough to be necropsied, and the cause of death was determined to be malnutrition and pneumonia.

The report summarizes results of disease workups conducted on ten bighorn captured in November 1986 in the South San Juan, Canyonlands National Park (Needles and Island in the Sky districts), and the San Rafael Swell. All had titers to bluetongue, parainfluenza-3, epizootic hemorrhagic disease, and bovine respiratory syncytial virus (BSVR). The San Rafael bighorn did not have titers to BSVR.

Predators were considered as a cause of low lamb survival, but the study concluded that they were not a serious factor in the San Juan unit. Climatological influence were also examined, and a correlation was found between lamb-ewe ratios and January to April precipitation. The researchers concluded that the drought occurring at the time of the study contributed to poor reproductive success by decreasing ewes' ability to give birth to healthy lambs and to feed their lambs and by making malnourished lambs more susceptible to disease.

Irvine, Charles A. 1969. The desert bighorn sheep of southeastern Utah. Utah Division of Fish and Game Publication #69-12.

The only information on disease was collected from 12 rams taken in the 1967 and 1968 hunts. There was very little evidence of parasites. Scabies and mites were found in the ears of all rams shot on the north side of White Canyon, but rams from the south side of the canyon had no scabies mites. There was no indication of pneumonia (as judged by inspection of the lungs of four animals), and blood samples, examined for brucellosis and leptospirosis, were negative.

Jessup, David A. 1985. Diseases of domestic livestock which threaten bighorn sheep populations. Desert Bighorn Council Transactions 29:29-33.

Bighorn sheep are susceptible to a number of livestock diseases and parasites. Historical records and modern investigations of bighorn disease problems and die offs reveal numerous examples. Jessup reviews specific diseases; several are pertinent to our area.

Scabies is a domestic sheep disease that affects bighorn. It has been greatly reduced in domestic livestock, but is still present. Jessup cites seven bighorn herd die offs from scabies since 1859. One of these was in Canyonlands from 1916 to 1922. However clinical attempts to transfer scabies mites from desert bighorn to domestic sheep left some question as to whether the same type of mite affects both wild and domestic sheep.

Chronic frontal sinusitis (CFS) is an important cause of mortality in desert bighorn. According to Tom Bunch, Utah State University, severity is greater in desert regions where bighorn concentrate at limited water sources. It is believed that CFS results from association with domestic sheep, and Bunch recommends at least a two-mile buffer between domestics and wild sheep.

Pneumonia: It appears that domestic sheep are more resistant to pneumophilic bacteria than bighorn and are able to carry strains of bacteria capable of causing acute pneumonia in bighorn. Jessup documents a number of cases in the wild and in labs where bighorn in contact with apparently healthy domestic sheep contracted and died from pneumonia. There are two types of pneumophilic bacteria: Pasteurella hemolytica, which is capable of causing progressive fatal pneumonia, and P. multocida, which seems to require predisposing viral infections and/or stress mediated immune suppression to become fatal.

Parainfluenza-III (PI-3) and bluetongue are viral diseases that have been implicated in bighorn mortalities. These diseases predispose bighorn to pneumonia. PI-3 is commonly associated with shipping fever and feedlot pneumonias of cattle and summer pneumonia of domestic lambs. Bluetongue is found in most wild ungulates as well as cattle. Culacoides gnats are necessary for bluetongue transmission. Jessup recommends two-mile buffer zones between bighorn and livestock water sources. Another livestock viral disease that may affect bighorn is bovine respiratory syncytial virus (BSVR).

Soremouth is a pox virus named for the painful sores it causes. It is common in domestic sheep and can remain viable in soil for up to ten years. It has most often been noted in overcrowded herds or under other stressful conditions.

King, Michael M. and Workman, Gar W. 1982. Ecology of the desert bighorn sheep in southeastern Utah; second year final report. BLM Contract Number YA-533-CTO-1068.

King investigated a number of aspects of bighorn ecology including movements and habitat utilization, forage utilization, livestock influence, human disturbance influence and diseases.

During this phase of the study, King noted an outbreak of some type of mouth disease in eight of twelve sheep of one band. Dr. Tom Bunch of Utah State identified the likely causes as vesicular stomatitis, bluetongue, or contagious ecthyma. Within a month, all bighorn had recovered. Otherwise the overall health of the herd was fairly good. Ten of 31 bighorn had titers to bluetongue. One ram shot during the hunt had scabies. None of the San Juan bighorn showed symptoms of chronic frontal sinusitis, but two Canyonlands rams had severe cases of this disease.

King, Michael M. and Workman, Gar W. 1983. Occurrence of contagious ecthyma in desert bighorn sheep in Southeastern Utah. Desert Bighorn Council Transactions 27:11-12.

King and Workman captured and drew blood from 79 bighorn from 1981 to 1983. These bighorn were from the Needles (NPS), North San Juan, or South San Juan (BLM) herds. Thirty percent showed titers to bluetongue, although no clinical cases were observed. Sinusitis and ear mites were also present in some of the bighorn.

In the fall of 1982, researchers noticed some sort of mouth disease in bighorn from the Blue Notch area. Blood samples were taken from these bighorn later, and the disease proved to be contagious ecthyma. All the bighorn recovered. This is a highly contagious viral disease, and the researchers thought it probable that it was transmitted from one animal to another at waterholes.

King, Michael M. and Workman, Gar W. 1983. Ecology of the desert bighorn sheep in southeastern Utah; third year final report. BLM Contract Number YA-533-CTO-1068.

In January 1983, blood samples were collected from 30 bighorn in Canyonlands National Park and the BLM study area. In 1982 bighorn in the Blue

Notch area had been noted to have mouth scabs, as a possible symptom of bluetongue or contagious ecthyma (CE). Analysis of blood samples showed 33% of the bighorn to be positive for bluetongue. However, none of these samples came from the Blue Notch area. At the same time, nearly all bighorn had titers to CE. King and Workman's conclusion was that the disease seen in 1982 was CE.

Stanger, Mark C. 1985. 1985 annual report; ecology of the desert bighorn sheep in southeastern Utah. BLM Contract Number YA-533-CTO-1068.

Stanger documented reproductive success, which was only 18 lambs/100 ewes compared to 49/100 the previous year. He found several dead lambs near springs, but they had been dead too long to determine any cause of death. He observed sick lambs who exhibited symptoms of contagious ecthyma and pneumonia.

HUMAN DISTURBANCE TOPICS

Bates, William J. and Workman, Gar W. 1983. Desert bighorn sheep habitat utilization in Canyonlands National Park. Desert Bighorn Council Transactions 27:25-28.

Distance to escape cover and the cover value of the area were variables most strongly correlated with bighorn use. Bighorn used steep slopes for resting and as escape terrain, and to a lesser degree for feeding. Blackbrush flats were used mainly as feeding areas. Forbs were used to a greater degree and shrubs to a lesser degree then their availability in the habitat. Ewes retreat to rugged canyons below the White Rim during lambing season.

Livestock grazing and human disturbance also affected habitat utilization. Human use appeared to cause a temporary displacement of bighorn on the White Rim, but the population has continued to increase in spite of human use. Bighorn have increased their range to include areas of the park formerly used by livestock, and the population has increased. Nearby areas still used by cattle and sheep are not used extensively by bighorn.

Haas, C. Shirlene, Workman, Gar W., and Bunch, Thomas D. 1990. Final report; an analysis of composition, distribution, and habitat use of reintroduced desert bighorn sheep in Arches National Park, Utah.

Haas looked at several human disturbance factors in Arches: vehicles on Highway 191, motorcycles, rivercraft and people on foot. The majority of the reactions she noted were a moderate response. Vehicles on Highway 191 do not generally disturb bighorn grazing on the flats across from the Atlas Mill. However, if people stop and get out of the vehicle, bighorn move off to steep slopes. Haas felt that bighorn were tolerating human disturbance in exchange for the use of high quality habitat along the river corridor and next to Highway 191.

King, Michael M. and Workman, Gar W. 1982. Ecology of the desert bighorn sheep in southeastern Utah; second year final report. BLM Contract Number YA-533-CTO-1068.

King looked at several types of human disturbance: mining, recreation, aircraft and vehicles. King did not have adequate data to draw conclusions on most of these activities. He did note that bighorn had extreme reactions to low-flying aircraft (below 300 yards)

King, Michael M. and Workman, Gar W. 1984. Ecology of the desert bighorn sheep in southeastern Utah; fourth year final report. BLM Contract Number YA-533-CTO-1068.

Desert bighorn response to human disturbance was evaluated from 1981 to 1983. Bighorn response was compared between the Red Canyon area, which had relatively high levels of human disturbance, and the White Canyon area, which had relatively low levels. Bighorn were deliberately harassed by vehicles and hikers and immediate response and distance fled were recorded. When bighorn remained in the presence of the harassing stimuli, actual time spent in the proportion of animals engaged in various behaviors were recorded to determine group wariness and activity budgets under harassed conditions. Bighorn were also observed under unharassed conditions to compare behavior between harassed and unharassed conditions.

Red Canyon bighorn responded more severely to harassment trials than White Canyon bighorn. Response by Red Canyon bighorn was generally running flight whereas White Canyon bighorn responded most often with non-flight behaviors. Group wariness was greater for Red Canyon bighorn than White Canyon bighorn when bighorn were exposed to continuous harassment. Activity budgets of unharassed bighorn were similar between areas, however, activity budgets of harassed animals differed significantly between areas particularly with respect to attention and feeding behaviors. Red Canyon bighorn were at attention longer and fed less than White Canyon bighorn under harassed conditions.

Miller, Gary and Smith, E. Linwood. 1985. Human activity in desert bighorn habitat: what disturbs sheep? Desert Bighorn Council Transactions 29:4-7.

During a six-year study of desert bighorn sheep in Western Arizona, the authors observed reactions of 1,150 sheep groups that were confronted by potential disturbances such as Interstate traffic, hunters, hikers, back country vehicle use and aircraft. Sheep exhibited a stronger reaction to one or two humans on the ground than to parked vehicles or a light airplane circling overhead. The closer sheep were to a disturbance, the farther they moved away. These observations corroborate earlier studies.

Stanger, Mark C. 1985. 1985 annual report; ecology of the desert bighorn sheep in southeastern Utah. BLM Contract Number YA-533-CTO-1068.

Stanger looked at river craft/bighorn sheep interactions in Cataract Canyon, classifying bighorn response as none, minor (watching, but no movement), moderate (walking away), or extreme (running). He also recorded interactions with aircraft. Most interactions resulted in no or minor response. Moderate responses were noted when boating parties approached bighorn (4% of responses); helicopters and sonic booms cause moderate and extreme responses.

SENSITIVE SPECIES:

RAPTORS
Priority II.6

STATEMENT OF PROBLEM

Raptors can be a sensitive indicator of changes in ecosystem health and often reflect changes in visitor use and distribution. The Southeast Utah Group has a minimum of 15 species of Falconiformes (Hawks) and seven species of Strigiiformes (Owls). The Peregrine falcon and bald eagle are endangered species. SEUG is legally required to monitor these species. The rest of the raptors are considered rare, sensitive or there is not sufficient information to determine their status. Due to the availability of NRPP funding for Peregrine falcons (1989-91) considerable information on this species is known. Other than incidental information on raptors obtained by visitor and employee sightings little is known of raptors from Canyonlands and Natural Bridges.

SEUG has at least five Peregrine falcon eyries. Prior work established occupancy and reproductive success. From 1989-91 SEUG received NRPP money to monitor these eyries and to survey likely habitat for additional eyries. The Peregrine falcon has been increasing dramatically on the Colorado Plateau and elsewhere and may soon be delisted. Pesticides remain a threat and in addition to monitoring known territories, research is needed into expansion or loss of birds, egg shell thinning and pesticide loading of prey species. Arches has had an extensive monitoring program for raptors since 1983. Resource Management must expand activities in this area to inventory and monitor raptors. At present the only activity likely to be funded is research into Mexican spotted owls which will be for the next three years. Monitoring of raptors is essential given the potential conflict between nesting raptors and increasing numbers of visitors.

RECOMMENDED ACTION

Management: The optimum need is for one GS-5 Wildlife Technician (.5 FTE) to monitor all known raptor territories during the reproductive season and to survey additional areas for new territories. Information on raptors is sorely lacking at Canyonlands National Park. Raptors are an important indicator species and as such, documentation of their distribution, condition and reproduction is critical. Information on owls is completely lacking and while NRPP funding is expected to be available to research Mexican spotted owls in the park for FY94-97. Additional information is needed on the other owls. The minimum standard will be to duplicate the effort that has been ongoing at Arches and to apply it to as much of the remainder of SEUG as possible.

Monitoring: Since 1992 SEUG has had to fund all monitoring work for Peregrine falcons. No funding exists to hire a seasonal to do this so the Natural Resource Specialist has had to accomplish the field work as time allows or has had to rely on other personnel to report sightings. It is a legal requirement that we continue to monitor Peregrine falcons. A minimum of 160 hours will be needed per year to accomplish this. Monitoring is expected to run at least ten years. Peregrine falcons are being considered for delisting and will be proposed as such in the next two years. Opposition by dissenting interested parties could delay delisting by two or three years. Following delisting SEUG will be responsible for monitoring this species for a minimum of five years.

FUNDING

Cost Estimate: $2,700 for personnel costs plus $1,500 in vehicle costs totalling $4,200/year.

Total Estimated Project Cost: $52,500 over the next ten years.

SENSITIVE SPECIES:

MEXICAN SPOTTED OWLS
Priority II.6

STATEMENT OF PROBLEM

Current Conditions: Though widely distributed throughout southwestern United States and Mexico, the Mexican spotted owl, Strix occidentalis lucida, apparently occurs in isolated subpopulations restricted to habitat "islands" (Ganey and Balda 1989, Willey 1991). Only one study has investigated the habitat ecology and distribution of Mexican spotted owls that inhabit canyon terrain in the Southeast Utah Group (SEUG) (Willey and Van Riper 1992). Regurgitated pellets gathered at sites in SEUG indicate that the owls are feeding primarily on woodrats, Neotoma spp. All known owl sites in the SEUG are characterized by steep sandstone canyons ranging in elevation form 4,500 to 6,500 feet.

In response to perceived threats to critical habitat and lack of adequate protective regulations the Mexican spotted owl was the focus of a petition to the USFWS for formal listing as a threatened species in 1989. The petition was accepted by the USFWS (Smith 1990) and an information retrieval phase for the subspecies was initiated. In November 1991, the USFWS formally published their proposal to list the southwestern subspecies as threatened. A period of public comment and further scientific review was established (Smith 1991). On March 16, 1993, the lucida subspecies was formally listed as threatened by the USFWS (Cully and Austin 1993).

Despite the immediate need for information on habitat requirements and factors related to population dynamics, few data are currently available. Subpopulations in the parks appear isolated by geographic barriers (e.g. desert plains, Lake Powell) and may collectively form a metapopulation (Shaffer 1985). Lacking are information on population distribution, maintenance, habitat-use and prey ecology in the rocky canyon landscape of the SEUG. Information on population status and habitat ecology in the SEUG area is needed for identification of critical habitat, to identify critical limiting factors, and to formulate recovery plans for the southwestern subspecies.

Past Actions: Previous inventories conducted in southern Utah, encompassing a wide range of habitat types, located spotted owls exclusively in steep and highly convoluted canyons (Gutierrez 1989, Rinkevich 1991, Willey 1991). These canyon habitats are very different from previously studied spotted owl sites to the south in Arizona (Ganey 1988). No formal inventory has been conducted in SEUG. All known and historic sites come from informal, anecdotal sightings recorded by park visitors, park staff, and researchers. No formal monitoring has occurred, however a study is underway investigating habitat use, home-range and movements of three owls in the Needles District of Canyonlands National Park.

RECOMMENDED ACTION

Management/Logistics: Investigation of the distribution and ecology of spotted owls in SEUG should be conducted by Department of the Interior (DOI) personnel, including both National Biological Survey (NBS) and National Park Service (NPS) team members. Contract labor is discouraged because expertise gained during project activities will leave the SEUG when the contractor completes the project. This loss of knowledge should be avoided. In order to maintain local (park based) expertise, standardized methods and research continuity/quality control, it is recommended that all inventory, monitoring and research activities be conducted by DOI personnel. Field crew members should be park based and supervised by a joint NBS/NPS management staff knowledge of SEUG ecosystem, spotted owl biology and SEUG landscape.

Research: Research needs include the following (in priority order):

1. Identification of suitable nesting, roosting and foraging habitat

2. Movements and home-range size, including seasonal or migratory movements of adults

3. Juvenile dispersal strategies and survival

4. Prey ecology

Preliminary work on topics 1 through 3 above are being conducted by the Colorado Plateau Research Center (CPRC) located at Northern Arizona University (NAU). All research activities should be coordinated by the CPRC/NAU to avoid duplication of effort, insure research continuity and efficiency, and provide biologists experienced with spotted owl biology. A hierarchical research program would include a research grade wildlife biologist filling the role of Spotted Owl Coordinator. The coordinator will design and manage the research program by creating a research team, comprised of NBS an NPS personnel that will iteratively address each research topic as funding is available.

Monitoring: Data on numbers of owls alone are not adequate for SEUG purposes and for full participation in recovery efforts. Long-term viability of current populations needs to be assessed in relationship to projected increases in visitor use and other park activities (e.g. campsite construction, road and trail construction). Isolated subpopulations in SEUG could be relatively isolated and extinction prone through human activities and stochastic events. Regular monitoring of SEUG populations is needed to determine their relative stability and to detect significant changes in population trends. There are no data available on reproductive rates or relative success of breeding efforts for the owl at the northern edge of its distribution. SEUG provides an opportunity for monitoring population change in a unique canyon environment.

Long-term monitoring of population trends would be accomplished by extending the standard Forest Service survey methodologies to annual monitoring of areas utilized by owls. Specific number and location of sites to be monitored will depend on the number of known sites in SEUG and represent a random sample of the population of sites available. Parameters would include: occupancy status (pair or single adult), and number of young sites should be conducted until five years after the owl is delisted. Study design and methods should be developed at NBS or NPS research units based on the Colorado Plateau, staffed with experienced spotted owl biologists and familiar with SEUG landscape and logistics.

Species/Process List: NPS Management Policies Chapter 4 and the Endangered Species Act, Section 2, 9c)1 assign to NPS, the responsibility to conserve Threatened and Endangered Species. The NPS has further responsibility to carry out habitat and population inventories utilizing standard protocols so as to assess population distribution and habitat affinities. Intensive inventories should be conducted for at least three years in SEUG to assess population distribution and abundance with some degree of assurity. The objective of the NPS program will be to establish baseline population figures and protocols used by the Forest Service so as to provide for comparability of data.

Reliable inventories are a necessary first step for credible NPS participation in development of the Mexican Spotted Owl Recovery Plan. Such information needs to be acquired as soon as possible so that it can be incorporated into the recovery plan now under development by the USFWS.

The NPS/NBS should establish an inventory team, consisting of three to four field personnel and a field supervisor/team leader, to survey SEUG units. The team would follow standard Forest Service protocol for canyon environs to survey a stratified sample of all available habitats within SEUG, with special effort given to areas judged suitable and marginal by habitat models developed

during research. All diurnal raptors encountered should be recorded during the surveys.

FUNDING

RESEARCH: Habitat use, adult movements, juvenile dispersal via radio telemetry, prey ecology:

Personnel: A field team comprised of four field technicians and one team leader will be needed, full time, for the breeding season. A field team comprised of two field technicians will be needed for any winter season activities. Field technicians should be GS-4, and the team leader a GS-5.

Field team members should be skilled in radio telemetry, habitat analysis, spotted owl inventory and monitoring, orienteering, remote wilderness camping and travel, small mammal trapping and handling, raptor handling and capture and 4x4 truck operation.

Transportation: The field teams will require two 4x4 trucks during breeding season activities and one 4x4 for the winter team activities. In addition, the telemetry project will require approximately eight to ten hours of flight time per week year round to track owls, with an estimated cost of $75/hour.

Supplies: Telemetry equipment including receivers, antennae, coaxial cables, earphones, paddles and 9-volt batteries will cost approximately $5,000. Approximately 35-40 radio-transmitters at $145 per unit will be needed. Backcountry equipment, including: tents, packs, cook sets, climbing gear and sleeping bags will cost approximately $10,000.

INVENTORY AND MONITORING

Personnel: A field team comprised of four field technicians and one team leader will be needed, full time, for the breeding season. The team will conduct both inventory and monitoring within SEUG. Field technicians will be GS-4, and the field team leader GS-5. The field technicians will be hired from 1 April through 31 August. The team leader will be hired from 1 March through 31 September. Field team members should be skilled in spotted owl inventory and monitoring, orienteering, remote wilderness camping and travel and 4x4 truck operation.

Transportation: The field teams will require two 4x4 trucks during breeding season activities.

Supplies: Backcountry equipment, including: tents, packs, cook sets, climbing gear, sleeping bags, headlamps, compass, batteries and radios will cost approximately $10,000.

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EXOTIC PLANT CONTROL
Priority II.7

STATEMENT OF PROBLEM

Russian knapweed, Centaurea repens, was discovered in Canyonlands National Park in 1991. It is an aggressive exotic that is of concern by all land managers in the Western United States. It has the capacity to replace native vegetation over large areas of suitable habitat if not controlled. In Canyonlands National Park, it was discovered to occur in the northwest corner of the park along the Green River. It covered an estimated seven acres in the Island in the Sky District from the park boundary to Potato Bottom. An 80 acre patch in Anderson Bottom has been reduced by 75%. Control of Russian knapweed is 85% complete.

In addition to Russian knapweed the park has infestations of musk thistle Carduus nutans, plumeless thistle C. acanthoides, Russian olive Eleagnus angustifolia, tamarisk Tamarix ramosissima, perennial pepperweed Lepidium latifolium, halogeton Halogeton glomeratus, yellow sweetclover Melilotus officinalis, horehound mint Marrubium vulgare, cheatgrass Bromus tectorum and puncture vine Tribulus terrestris. These species exist in varying degrees of threat to park resources. Their threat needs to be adequately inventoried, assessed and prioritized as to control needs. Several other species of exotic plant occur in the area and may eventually infest the park if control efforts by adjacent land owners fail. These species include Dyer's woad Isatis tinctoria, dalmation toadflax Linaria dalmatica, jointed goatgrass Aegilops cylindrica, Canada thistle Cirsium arvense, yellow starthistle Centaurea solstitialis, diffuse knapweed C. diffusa and black henbane Hyoscyamus niger.

RECOMMENDED ACTION

Exotic plants are generally very aggressive invaders that can replace native vegetation over large areas of habitat, sometimes forming pure stands. This is especially true where the native vegetation has been disturbed. Infestations could be wide spread. Complete inventory of susceptible habitat is needed. Control can be more easily accomplished on known infestations if there is an adequate inventory and control efforts are prioritized. If control is not initiated or is not effective, exotic plant infestations could spread throughout the park eliminating stands of desirable native plants.

FUNDING

Cost Estimate: $15,000 annually as part of the permanent park base.

Total Estimated Project Cost: $15,000 per year. Insufficient data exists to ask for more funding but may likely be needed. The $15,000 is the minimum needed to control exotic plants and should be part of the permanent park base. This will probably be cheaper than no action as future spending for crisis situations that will undoubtedly develop will easily exceed this figure.

APPENDIX IV. PROJECT STATEMENTS FOR UNRANKED CRITICAL, MORE IMPORTANT AND IMPORTANT RESEARCH PRIORITIES

BENTHIC MACROINVERTEBRATES
Priority: More Important

STATEMENT OF PROBLEM

The Colorado River is the major waterway through much of the desert southwest. It is a large, warm, shallow, sediment-rich river. Canyonlands National Park centers around the confluence of the Green and Colorado Rivers. After joining with the Green River, the Colorado River flows through a large canyon known as Cataract Canyon into Glen Canyon National Recreation Area and then into Lake Powell (created by the Glen Canyon Dam). The Colorado River has no major dams above the Glen Canyon Dam and the Green River has only the Flaming Gorge Dam. While the Glen Canyon Dam has created significant impacts on natural river flows and habitats through the Grand Canyon, waters above Lake Powell are relatively unimpacted. All four species of Colorado River endangered fishes are supported in Canyonlands National Park, including Colorado squawfish Ptychocheilus lucius, humpback chub Gila cypha, razorback sucker Xyrauchen texanes and bonytail chub Gila elegans.

Canyonlands National Park (CANY) has a variety of other natural water sources. There are potholes, pools fed from seeplines in canyon alcoves, pools fed by below ground percolation, plunge pools (slickrock pouroffs fed only during flash floods or heavy spring run-off), springs that gush from rock walls and streams that flow continuously. Substrates vary from slickrock to deep, soft sand. Many of these water sources support macroinvertebrate populations.

In recent years, it has become widely recognized that reliance on chemical-specific analysis is insufficient for optimum characterization of true water quality or optimum protection of aquatic life. In keeping with the goals of the Water Quality Act of 1987, the Environmental Protection Agency (EPA) is encouraging states to develop 1) biocriteria for inclusion in state water quality standards and 2) instream bioassessment methods for measuring compliance with the biocriteria. Biocriteria and standardized bioassessment methods are useful for the following applications: 1) use attainability analyses, 2) identifying areas where site-specific criteria (both biological and chemical) are needed, 3) characterizing the value of high quality waters as required by anti-degradation standards, 4) determining the need for additional controls, 5) identifying previously unknown sources of pollution and 6) measuring attainment of the fishable/swimmable goals in the Water Quality Act of 1987. In Ohio, it was determined that twice as many streams were classified as impaired when biological condition data was part of the criteria than were classified as impaired when attainment of chemical-specific standards was the main criteria.

In May of 1989, the Environmental Protection Agency published their new guidance for rapid bioassessment protocols for fish and invertebrates in creeks and small rivers. All 50 states are being encouraged to come up with similar versions for approval by EPA. Utah has been one of the slower states to respond. When the Utah Department of Environmental Quality (UDEQ) was last queried, they indicated that they planned to use a protocol similar to the Biotic Condition Index (BCI) developed by Fred Mangum and in recent use by the US Forest Service and Bureau of Land Management (BLM). However, they did not have firm plans to develop protocols for bigger, sediment-laden rivers like those in Canyonlands.

Understanding the natural functioning of aquatic ecosystems is necessary for effective water quality and water resources management. Since macroinvertebrates are a critical part of these ecosystems, characterizing the distribution and population dynamics of these organisms is an essential part of understanding the natural functioning of these aquatic systems. It is crucial for the National Park Service (NPS) to have baseline information on macroinvertebrate populations in case of catastrophic events such as oil or toxic waste spills, and to measure visitor impacts. Currently, information on macroinvertebrate sampling methodology, species

composition and biomass, and species sensitivity to anthropogenic impacts in this area is scarce or non-existent.

An ever present threat exists from hazardous waste spills that could occur on any of the bridges over the Green or Colorado Rivers. Such a disaster could be devastating to the macroinvertebrates and to the endangered fish populations that feed on them. It is imperative that we be prepared to make a Natural Resource Damage Assessment in the event of a hazardous spill in the river to preclude legal problems similar to those that followed the Exxon-Valdez oil spill. Uranium tailings located near the Colorado River at Moab, Utah may also be affecting the river ecosystem if radioactive elements are leaching out. Urbanization, pollution, irrigation and sedimentation also continually impact the Colorado River system.

Other natural water sources in the park face threats including visitor use, trespass grazing, oil and gas development and internal development. The most prevalent threat is visitor use, as springs are frequently used by visitors for bathing. The influence this has on macroinvertebrate populations or general water quality is unknown.

The Colorado River above Lake Powell is the best example of the original state of the Colorado system prior to major developmental impacts. Consequently, this stretch could act as a control to the systems in the Grand Canyon. The Colorado River differs from many western rivers, in that it carries significantly higher sediment loads. The Glen Canyon Environmental Studies Group (GCES) has conducted an intensive macroinvertebrate inventory and has established a monitoring program for their river system. Their data will be more valuable when they can compare it to a similar, but relatively undisturbed system.

RECOMMENDED ACTION

Project objectives include:

1. Determine whether any protocols have been developed for other large, sandy rivers. Determine whether standardization is possible with sampling protocols, such as those developed by the USGS NAWQA program, the UDEQ, the EPA, the GCES program and other programs sampling invertebrates in large, sandy rivers.

Standardization with similar programs would be desirable, but may be impossible. The Colorado River is unlike most other western rivers, in that it carries a heavy sediment load. Most macroinvertebrate sampling has not been done in rivers of this type. There is work being done on the Missouri River, another large, sandy river, which may be comparable to the Canyonlands system. The stretch of the Colorado River through the Grand Canyon is also very different from Cataract Canyon. It will be desirable to establish a protocol that works well in Canyonlands, which may serve as a model for other large, sandy rivers.

A preliminary sampling trip was conducted in October 1993, involving CANY, GCES, NPS Water Resources Division (WRD), UDEQ, Brigham Young University (BYU) and Bio/West. GCES sampling methods were used on the Green River and on the Colorado River above and below the confluence. Hess samples and ponar samples were collected. The Hess samples were stirred, but the rocks were not scrubbed. The ponar sampler often had difficulty grabbing sediments, particularly in deeper water. The methods were workable, but were found to be time consuming and costly for the amount of information retrieved. Their methods are not compatible with any other sampling schemes. The Colorado is rigorously sampled downstream by GCES and upstream by NAWQA. It was recommended by several of the trip participants that Canyonlands adopt a more simple approach, such as a modification of EPA's Rapid Bioassessment protocol. This is what the state of Utah anticipates adopting.

2. To develop rapid bioassessment protocols for various substrates including: (1) shifting sand runs, (2) backwaters, (3) vegetated cutbanks and (4) silt-sand beaches, in the Colorado and Green Rivers for benthic macroinvertebrates and to compare the results in terms of species composition, frequency and relative biomass on a temporal basis. Appropriate habitat types will be prioritized by the contractor. Conduct a thorough review of existing protocols and their rapid bioassessment methods. Experiment with various methods in Canyonlands. The sampling protocols must work well in a large river system with a sediment-rich sandy bottom. Sampling should occur at least four times per year, for legal purposes and to develop an adequate baseline.

3. Identify candidate sources of catastrophic perturbations that could affect water quality, macroinvertebrates, or fishes in the Park. The protocols will be developed in such a way that the National Park Service will be able to use the collected data to assess the level of environmental damage from a catastrophic event, such as an upstream oil spill or breached waste retention pond.

4. Conduct a literature search of sensitivity by fish and macroinvertebrate species in the Park to potential toxicants and pollutants, and develop a Rapid Response Plan. This plan would outline immediate actions that would be required following a pollution disaster in the river.

The literature search should characterize other available protocols and identify sensitivity levels for important fish and macroinvertebrate species found in Canyonlands National Park. This effort will identify those resources most susceptible to particular toxicants or perturbations. This search will provide the background for a rapid response plan, detailing reaction and activities needed to document a perturbation in Canyonlands National Park. This plan should include a step by step description of response times, sample sites, notes, photographs, sample collections and contacts for additional analyses.

5. Develop a monitoring protocol to assess visitor impacts on non-riverine aquatic systems, and determine whether such monitoring will provide useful information. Determine whether macroinvertebrates show any susceptibility to sunscreens.

Development of protocols will require sampling trips on the Green and Colorado Rivers, including Cataract Canyon. Various methods will be experimented with such as those of UDEQ, NAWQA, EPA and the Grand Canyon. A surveillance of areas upstream and adjacent to Canyonlands National Park will be necessary to identify potential sources of pollutants to the river corridor. Pipeline crossings should be identified, as well as waste disposal ponds, highway and railroad crossings and industrial sites. Materials stored or shipped in these areas should be identified in order to provide a risk assessment for aquatic resources in the Park.

Sampling will be conducted in several types of small springs with varying substrate types to determine what methodologies are effective in this area. A species list will be generated from the data obtained.

The products of this investigation will be:

a. Recommended Rapid Bioassessment Protocols for use on the Colorado and Green Rivers, with thorough documentation of why key parts of the protocols were chosen for the particular sandy river habitat typical of Canyonlands. Mesh size for invertebrate collections should be specified along with a rationale as to why other mesh sizes were rejected (currently every agency uses a different standard).

b. Long-Term Monitoring Plan. A report or manual including protocols and procedures for future monitoring will be provided for the Park. This will constitute the final report and should detail work accomplished and results. A section on monitoring of other Canyonlands water sources may be included in this report or added as a separate report.

c. Rapid Response Plan. This plan would make recommendations for

management of the river system, identification of threats and methods for continued monitoring. It would outline what data would be necessary to prepare a Natural Resource Damage Assessment.

Sampling and surveillance trips will be conducted during the first year of the project. Trips may be conducted in the second year if necessary. Trip reports will be prepared following each trip to summarize activities and findings. A long-term monitoring plan including sampling protocols will be developed in the second year of the investigation, following necessary sample trips. A final version of recommended rapid bioassessment protocols, accompanying documentation and a rapid response plan will also be developed in the second year, that identifies fish and macroinvertebrate species sensitivity and details recommended actions for resource agencies faced with a catastrophic event on one of the major rivers. Average rapid bioassessment scores, as well as typical water quality parameters will be presented in the long-term monitoring plan to begin to establish a baseline for aquatic resources in Canyonlands National Park.

Estimated time for completion: two years

FUNDING

ANNUAL COSTS	
LABOR & OTHER COSTS	$13,000
TRAVEL	5,000
EQUIPMENT	2,000

Estimated cost of the project: $20,000 per year

INVENTORY OF SEUG AVIFAUNA
Priority: More Important

STATEMENT OF PROBLEM

The principal objective of this study will be to inventory the avian communities of National Parks under the auspices of the Southeast Utah Group (SEUG). The goal will be to provide park staffs with a complete listing of all avian species found within their park. This listing will include those birds that breed within the park, and those that are only transients. Moreover, it will differentiate between migrants, partial migrants and residents. Each of the avian species will be identified to duration of presence and in what specific major vegetation types they occur. Without information on avian distribution and numbers within the park, resource managers will not be able to properly assess the potential impacts of their actions (e.g., habitat alteration, prescribed fire) on the avian component of their park resources.

There has been some baseline work done on describing the avian species and in what habitats that they occur in the three SEUG park areas. Point-counts similar to Emlen transects have been conducted by park staff in many habitats between 1985 and 1992. Transects were run in riparian zones in 1993 by a contractor. Breeding bird census plots (spot mapping plots) have been conducted in Arches for 11 years and at the Island in the Sky for three years, both in pinyon-juniper communities. Breeding bird surveys (standard road surveys) have been conducted in Arches and the Island for three years. Another has been run on BLM land adjacent to Canyonlands to the north. Behle et al. (1985) compiled a field guide and check list of the status of Utah birds, but this document is currently out of print. No completed effort has been done on documenting the avian communities and their habitat associations, nor has any winter work been done on bird communities in the parks.

RECOMMENDED ACTION

Management: The resource management staff will be responsible for assisting with the surveys. In this manner, they will obtain an insight into the experimental design of the study, and how the specific census techniques will be carried out. More importantly, the RM staff will be responsible for carrying out the monitoring phase of this study to look at the long-term population trends of the avian communities of the parks.

Research: Research will involve a series of census techniques. Each technique will act as a control for more accurately determining densities of birds in the various ecosystems of the park. Recommended techniques will be the variable circular plot, accompanied by the strip transect and spot mapping methods. Each of the census locations should be within a unique vegetation type. Prior to the census, stations should be established in at least ten locations of each vegetation type. All major vegetation types within the park should be represented. Simultaneously with the density counts, researchers should conduct observational counts which will be later used to determine an index for relative densities of birds. This latter technique will be the basis for subsequent monitoring efforts.

Monitoring: Monitoring will be carried out in a random sample of the original study census plots. The sampling scheme should, however, be stratified so that an equal (but smaller) number of census locations occur in **all** of the representative vegetation types within the park. The monitoring technique will yield relative densities of birds. An index can be deprived from the original census data so that it can be used to project a close estimate of actual bird species densities from the monitoring data.

FUNDING

Personnel:

- One student technician for three years at $10,000 per year

- Field helpers (3) for a three month period each summer at $2,000 per student

Transportation:

- At least four trips to the park each year at $500 per trip/ participant.

- Car rental for the summer at $1,000/month

- Per diem for technician at $25/day

Supplies:

- Spotting scopes, binoculars, mist-nets and poles, banding supplies, etc. at $1,000/year. Other field gear at $2,000/year for two years.

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BATS
More Important

STATEMENT OF PROBLEM

Current Conditions: Nongame animals often have been overlooked in biological surveys. Bats are nocturnal and require unique equipment and techniques to study, and so are even more likely to be omitted from biological inventories. Little is known of the status and distribution of bat communities in southeastern Utah.

Many bats use mines, caves and fissures in cliffs for roosts. Roosting sites are believed to be a primary constraint in the distribution of bats. These sites may be susceptible to damage by, and pose a threat to, park visitors. Identifying roost sites will assist in protecting bats and visitors, and will allow the parks to begin implementing the Federal Cave Resources Protection Act. Bats are most vulnerable at their roost sites, so it is critical that the NPS carefully consider activities that may impact known or unknown roosts.

Bats use surface water and surrounding areas for foraging and drinking. In xeric areas like southeastern Utah, riparian areas are likely to be as important as roosting sites in determining distribution patterns of bats. Surface water in the parks should be identified and monitored for use by bats.

A greater understanding of the status, distribution, relative abundance, habitat use, roosts and feeding and watering areas of bats will assist park managers in planning for future development. And it assures that the unique needs of bats are incorporated into management plans.

Past Actions: An inventory of bats was begun by personnel of the National Ecology Research Center, U.S. Fish and Wildlife Service (USFWS), in Arches National Park (1991) and Natural Bridges National Monument (1991, 1992). Reports from these studies are on file at SEUG.

RECOMMENDED ACTION

Management & Logistics: Bat research in the parks should be conducted by qualified research biologists in cooperation with National Park Service biologists and resource managers. Logistics will involve access and transport of personnel to remote sites.

Research: Research should initially focus on obtaining baseline data.

Objectives are stated first; methods are in parentheses.

1. Assemble information on historic records and specimens of bats from the parks. (Contact museums for specimen records, examine specimens where necessary, compile reference material and summarize).

2. Determine the presence, relative abundance, seasonal occurrence and distribution of bats on the parks. (Mistnetting, ultrasonic monitoring, chemiluminescent and radio tracking of flying bats).

3. Identify sites that are used as day or night roosts, maternity roosts, or hibernacula; determine most effective means of protection and human safety concerns associated with roosts, especially caves and mines (Search for roosts and, when found, record location, size, structure, slope, aspect, temperature, surrounding habitat, threats, accessibility, vulnerability and means of protection).

4. Identify ephemeral and permanent surface water used by bats. [Search for and mistnet appropriate sites; record location, type (e.g., spring, stream, pond), size, surrounding habitat, threats and protective or management measures needed].

5. Initiate a public education campaign to acquaint park visitors with resident bats, concerns for their welfare and ongoing research and management activities.

Once research studies have elucidated basic natural history of resident bats, more elaborate research questions can be formulated. It may be

of interest to determine what roles are played by bats in ecosystem functioning. Are they affected directly or indirectly affected by impaired ecosystem functioning caused by past and/or present disturbances? These questions and others may be appropriate for university researchers and graduate students.

Monitoring: The parks should establish permanent transects and monitor bat activity with ultrasonic detectors. Researchers should establish a protocol for monitoring that provides for a predetermined effort in specific habitats, so that results can be compared across sites and years. Trained park personnel can conduct these annual monitoring efforts and can monitor roosts by documenting bats exiting roosts at dusk. Searches for roosts other than caves and mines is time consuming and is rarely successful. These searches should be limited to areas that may be impacted by planned development in the park, where bat activity is high, or where roosting information on individual species is desired. Park buildings, especially older structures, should be examined for use as roosts prior to destruction or remodelling.

Species list: The USFWS has provided comments on earlier species lists, and has compiled a current list for Natural Bridges National Monument. Initial work should include capturing bats and determining species occurrence in the parks. Mistnetting should be conducted during the summer to monitor the status of species resident to the park, and in the spring and fall to document migrating species. Potential hibernacula, generally more extensive sheltered caves and mines, should be examined during winter. Summer roosts should be located by ground searches near areas of known bat activity, and by affixing chemiluminescent-filled gelatin capsules to captured bats. Released bats can be followed visually, and their flight behavior, flight path and direction observed. A small number of bats should be collected and deposited in a museum as voucher specimens.

FUNDING

Personnel: The principal investigator(s) undertaking this research should possess an understanding of bat ecology and be familiar with current, relevant literature. Knowledge of techniques for locating, capturing, identifying and monitoring bats is essential, as is an understanding of the potential negative impact of disturbance on roosting bats. Some long term monitoring (e.g. transect and roost monitoring) can be carried out by properly trained park personnel. Some aspects of bat research in the parks may be appropriate as graduate student projects supervised by qualified biologists. In general, field work should be conducted by teams of two or more individuals.

Transportation: Access to sites where most research can be conducted will require transportation by 4X4 vehicles capable of carrying equipment, and possibly by boat. Hikes into remote areas will be necessary, and depending upon the specific activity, field crews will need to be self-sustaining for varying lengths of time. The NPS will need to provide access and permission to enter sites. In some instances, technical climbing ability may be required to enter roosts in cliff faces. Field personnel that enter caves or mines, that use boats, or that conduct technical climbing, should receive appropriate safety training as required by Federal and State regulations.

Supplies: Basic supplies required for the study of bats include mist nets of appropriate size and mesh, collapsible and non-collapsible netpoles, ultrasonic detectors, data sheets and associated supplies. A Federal or State collecting permit is required for the purchase of mist nets. Provisions for retaining and preparing voucher specimens, headlamps, cloth bags for bats kept for examination, chemiluminescent fluid and capsules, and powerful hand-held flashlights are needed. Bat bands, ropes and technical climbing gear may be needed. Two-way radios will be required. Personnel handling bats should be protected with rabies preexposure immunization by human

diploid cell vaccine and titers should be checked as recommended by medical personnel. Field crews will require tents, personal camping gear, food and water for extended time spent in remote areas.

Estimated costs: A minimal effort at one park would cost between $5,000 and $10,000 per year.

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INVERTEBRATE COMMUNITIES IN RIPARIAN VEGETATION:
COMPARISONS BETWEEN TAMARISK AND NATIVE TREE DOMINATED SYSTEMS
Priority: More Important

STATEMENT OF PROBLEM

Objectives:

1. Inventory invertebrates on tamarisk and describe invertebrate community structure--species composition, species abundances, etc.

2. Inventory invertebrates in cottonwood-willow communities, and describe community structure.

3. Compare invertebrate communities quantitatively in terms of species, guilds and functional group composition.

4. Develop database that can be incorporated into ecosystem studies comparing native and tamarisk dominated systems, i.e., how do invertebrate differences translate into observed differences in vertebrate communities, productivity of the two systems, etc.

APPENDIX V. PROJECT STATEMENT AND COST SUMMARY

PROJECT STATEMENT AND COST SUMMARY

PRIORITY/ TITLE	YEARS REQUIRED	TOTAL COST (*IN THOUSANDS OF DOLLARS*)
II.1 ECOSYSTEM CHARACTERIZATION: CHARACTERIZATION OF MAJOR ECOSYSTEMS IN SEUG	3 HABITATS	$900K (300K/HABITAT)
II.1 ECOSYSTEM CHARACTERIZATION: MONITORING OF MAMMALS IN SEUG	ON-GOING	UNKNOWN
II.1 ECOSYTEM CHARACTERIZATION: COMPARISON OF INVERTEBRATE COMMUNITIES	UNKNOWN	UNKNOWN
II.1 RIVER FLOWS, SEDIMENT TRANSPORT & RIPARIAN VEGETATION: STREAMFLOW AND RIPARIAN VEGETATION IN THE GREEN AND COLORADO RIVERS, SEUG	5	1,000K (200K/YEAR)
II.1 RIVER FLOWS, SEDIMENT TRANSPORT & RIPARIAN VEGETATION: DEVELOPMENT OF A LONG-TERM MONITORING PLAN OF RIVERINE AQUATIC RESOURCES IN CANYONLANDS NATIONAL PARK, UTAH	2	15K/YEAR
II.1 VISITOR IMPACTS TO ECOSYSTEMS: SOIL SURFACE DISTURBANCES	3	75K (25K/YEAR)
II.1 VISITOR IMPACTS TO ECOSYSTEMS: PLANT COMMUNITY DYNAMICS IN GRASS-SHRUB STEPPE	UNKNOWN	UNKNOWN
II.1 VISITOR IMPACTS TO ECOSYSTEMS: EFFECTS OF VEGETATION ON INVERTEBRATE/ VERTEBRATE COMMUNITIES	UNKNOWN	UNKNOWN
II.1 VISITOR IMPACTS TO ECOSYSTEMS: SOIL FOODWEB CHARACTERIZATION	UNKNOWN	UNKNOWN
II.1 VISITOR IMPACTS TO ECOSYSTEMS: WATER QUALITY	UNKNOWN	UNKNOWN
II.4 GEOGRAPHICAL INFORMATION SYSTEM (GIS): DEVELOPMENT AND APPLICATION	2 VEGETATION MAP ON-GOING	46.3K 100K 50K
II.5 ENDANGERED SPECIES: FISHES	10	150K (1.5K/YEAR)
II.6 SENSITIVE SPECIES: DESERT BIGHORN SHEEP	2	29.5K
II.6 SENSITIVE SPECIES: RAPTORS	10	52.5K
II.6 SENSITIVE SPECIES: MEXICAN SPOTTED OWLS	1	87K
II.7 EXOTIC PLANT CONTROL	ON-GOING	15K/YEAR

APPENDIX VI: WORKSHOP PARTICIPANTS

WORKSHOP PARTICIPANTS

Jayne Belnap/SEUG
National Biological Survey:
soil biota

Mike Bogan/USFWS
National Biological Survey:
small mammals, bats

Jim Ehlringer
University of Utah:
plant physiological ecology

Tim Graham
National Biological Survey
University of California-Davis:
reptiles, small mammals,
terrestrial invertebrates

Kimball Harper
Brigham Young University:
vegetation communities,
rare plants

Elaine Ingham
Oregon State University:
soil macro- & micro-fauna,
ecology, effects of disturbance

Bill Jackson/NPS
Division of Water Resources:
water resources

Dave Johnson
The College of Santa Fe:
small mammals

Jim MacMahon
Utah State University:
restoration of desert systems,
ecosystem functioning, terrestrial
invertebrates

Miles Moretti
Utah Div. of Wildlife Resources:
riparian plants and animals, large
mammals, raptors

Linda Seibert
Moab District BLM:
large mammals, bighorn sheep

Rich Valdez
Bio/West:
aquatic biology, fish, invertebrates,
chemistry

Charles Van Riper III
National Biological Survey
Colorado Plateau Research Center
Northern Arizona University:
birds, panel moderator

Ed Wick/NPS
Water Resources Division
Colorado State University:
fishes

Tara Williams/SEUG:
vegetation, community ecology

ADDITIONAL PANEL MEMBERS FOR REVIEW
OF PRIORITIZATION

NPS

Walt Dabney,
Superintendent, SEUG

Tony Schetzsle,
Chief Ranger, CANY

Larry Fredrick
Chief Interpreter, CANY

Larry Thomas
Chief of Resource Management, SEUG

Craig Hauke
Natural Resource Specialist, SEUG

Nancy Coulam
Archeologist, SEUG

Noel Poe
Superintendent, ARCH

Jim Webster
Chief Ranger, ARCH

Steve Chaney
Superintendent, NABR

Jim Dougan
Chief Ranger, NABR

BLM

Roger Zortmann
Moab District Manager

Russ van Koch
District Recreation Planner

Brad Palmer
Grand Resource Area Manager

Joe Cresto
Area Wildlife Biologist

Bob Turri
Acting San Juan Area Manager

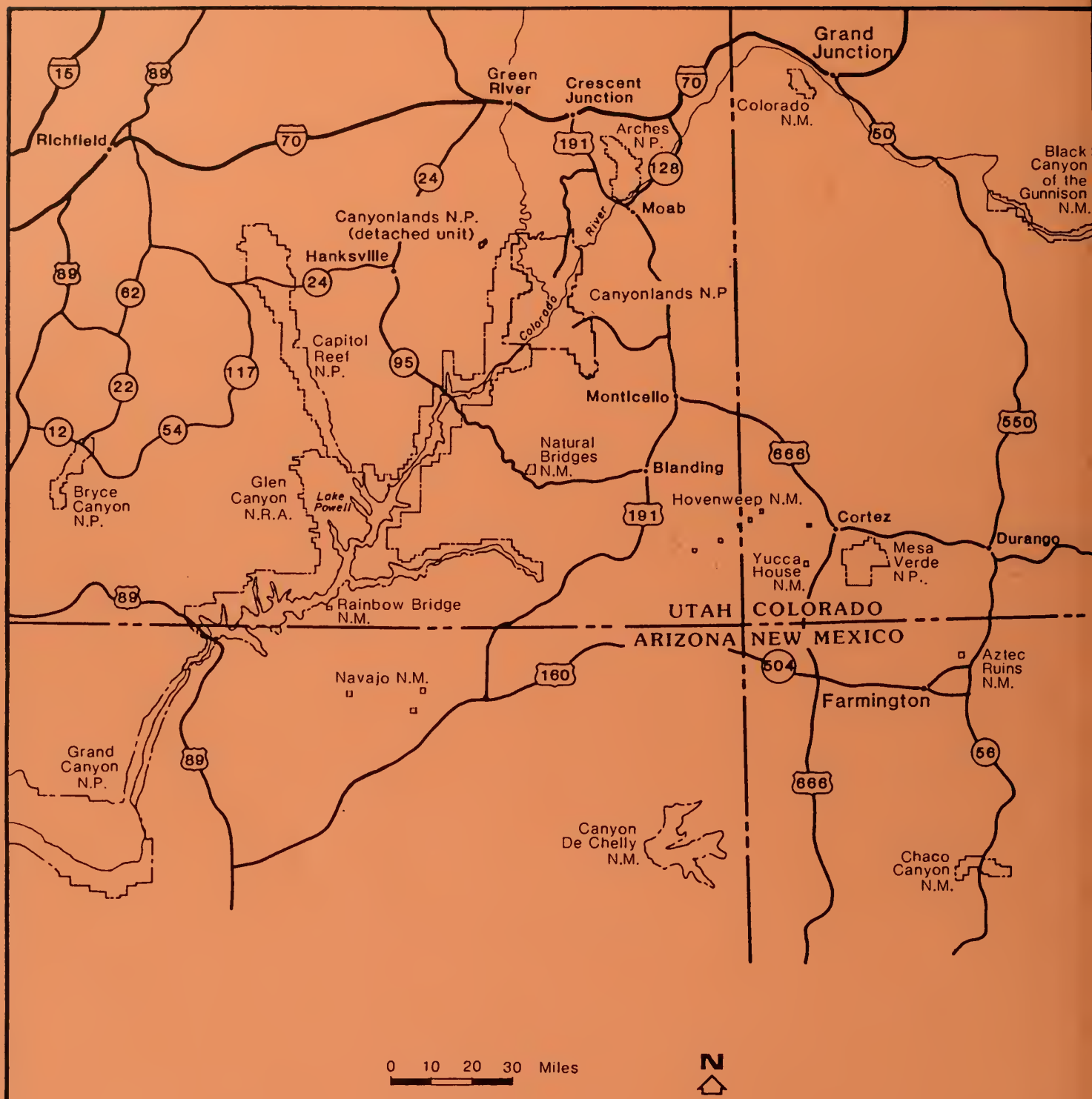
U.S.F.S.

Jerald Shaw
Moab District Ranger

Heather Musclow
Moab District Biologist

Lee Bennett
Monticello District Ranger

Ana Egnew
Monticello District Biologist



Vicinity Map

Canyonlands National Park

United States Department of the Interior – National Park Service